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# DERIVATION AND REGIONALIZATION OF UNIT HYDROGRAPH PARAMETERS FOR ILLINOIS (DAM SAFETY PROGRAM)

*By*

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# INTRODUCTION

In August 1972, the 92nd Congress of the United States authorized the National Dam Safety Program by legislating Public Law 92-367 -- The National Dam Inspection Act. This Act authorized the Secretary of the Army, acting through the Chief of Engineers, to initiate an inventory program for all dams satisfying certain size criteria, and a safety inspection of all non-federal dams in the United States that are classified as having a high hazard potential or significant hazard potential because of the existing dam conditions. A dam is defined as an impounding structure with 25 feet or more height above the streambed or with 50 or more acre-feet (ac-ft) of storage capacity at maximum water storage elevation. The Act does not apply to structures less than 6 ft high or with less than 15 ac-ft storage capacity (Corps of Engineers, 1980).

The three hazards classifications considered are:

.1. High hazard potential: Dam breach may cause flooding and serious damage to occupied dwellings located in the floodplain. It presents a high potential for loss of human life.

2. Significant hazard potential: Dam failure presents the possibility of loss of human life and damage to structures and facilities in the floodplain. A breach may result in substantial economic loss.

3. Low hazard potential: Dam failure has a remote possibility of loss of life, and damage to structures and facilities in the floodplain would be minor.

The Corps of Engineers (1980) lists 920 federal and non-federal dams in Illinois meeting or exceeding the size criteria as set forth in the U.S. Public Law 92-367. A summary of these dams by hazard potential classification, type of dam, reservoir use, and structural height is given below.

A. Hazard Potential Classification

| Classification | No. of dams | % |
|---|---|---|
| High hazard potential | 122 | 13 |
| Significant hazard potential | 241 | 26 |
| Low hazard potential | 557 | 61 |

B. Type of Dam Construction

| Type | No. of dams | % |
|---|---|---|
| Earth | 890 | 96 |
| Gravity | 23 | 3 |
| Rockfilled | 2 | <1 |
| Arch | 1 | <1 |
| Other | 4 | <1 |

C. Reservoir Use

| Use | No. of dams | % |
|---|---|---|
| Recreation | 658 | 72 |
| Water supply | 118 | 13 |
| Flood & erosion control | 70 | 8 |
| Small farm ponds | 19 | 2 |
| Navigation | 10 | 1 |
| Hydroelectric | 6 | <1 |
| Irrigation | 4 | <1 |
| Other | 35 | 4 |

D. Structural Height, H

| Range | No. of dams | % |
|---|---|---|
| $6' \leq H \leq 10'$ | 32 | 3 |
| $10' < H < 25'$ | 346 | 38 |
| $25' \leq H < 40'$ | 371 | 40 |
| $40' \leq H < 100'$ | 166 | 18 |
| $100' \leq H$ | 5 | <1 |

It is evident that 96% of the 920 dams inventoried are earth dams, for which the dominant causes of failure are overtopping and piping and, to a lesser extent, unsatisfactory construction and maintenance and foundation problems.

The failure by overtopping of the dams during very high inflow conditions results mainly from inadequate spillway capacity and insufficient freeboard. The Division of Water Resources of the Illinois Department of Transportation, acting on behalf of the Corps of Engineers, as well as the Corps of Engineers, have been preparing inspection reports or having them prepared by consultants and engineering companies for high-hazard-category dams. The inspection report contains the project description; engineering data for construction, operation, and maintenance; results of visual inspection; hydraulic and hydrologic evaluation of the spillway and outlet works for different inflow flood hydrographs; project plan and downstream channel; etc. An integral part of the hydraulic and hydrologic evaluation is an investigation of the adequacy of a spillway to handle floods of various frequencies without endangering the structure or causing dam failure because of overtopping. These evaluations require information on storms of various frequency, their depth-area-duration relationships, and the soil moisture conditions at the beginning of a design storm, as well as suitable unit hydrographs for converting the design storms into flood hydrographs. The unit hydrographs are derived by a number of methods,' some of which are untested for Illinois conditions and are possibly of dubious accuracy for watersheds in Illinois. Some of the methods in use are summarized below:

1. The watershed area is subdivided into smaller subareas. A synthetic unit hydrograph is developed for each of the subareas through use of the Soil Conservation Service procedure. The subarea hydrographs are then lagged by appropriate travel time and accumulated at the basin outlet to obtain the total watershed synthetic unit hydrograph.

2. A synthetic unit hydrograph is derived by Snyder's method (1938). Snyder analyzed a large number of hydrographs from drainage basins in the Appalachian Mountain region in the United States and developed the following equations:

$$t_p = C_t \, (L \, L_c)^{0.3} \tag{1}$$

$$t_r = t_p/5.5 \tag{2}$$

$$q_p = 640 \, C_p/t_p \tag{3}$$

$$t_{pR} = t_p + 0.25 \, (t_R - t_r) \tag{4}$$

$$q_{pR} = 640 \, C_p/t_{pR} \tag{5}$$

The notations in the above equations are:

$t_p$ = lag time from midpoint of effective rainfall duration $t_r$ to peak of unit hydrograph, hr

$t_r$ = duration of effective rainfall, hr

$t_R$ = duration of effective rainfall other than standard $t_r$, hr

$t_{pR}$ = lag time with effective rainfall duration $t_R$, hr

$q_p$ = peak discharge for standard duration $t_r$, cfs/mi$^2$

$q_{pR}$ = peak discharge for $t_R$ duration, cfs/mi$^2$

$L$ = river miles from basin outlet to upstream limit of drainage area

$L_c$ = river miles from basin outlet to center of gravity of drainage area

$C_t$, $C_p$ = coefficients

The average value of $C_t$ and $C_p$ varies from one region to the other.

From a given hydrograph of a drainage basin, the unit hydrograph can be obtained from the above equations with values of L and $L_c$ obtained from the basin map. For an ungaged basin, the values of $C_t$ and $C_p$ can be determined for nearby gaged stations and interpolated for the station under consideration. The width of the unit hydrograph, at 75 and 50 percent of the peak discharge in hours, can be estimated from the following empirical equations (Corps of Engineers, 1959):

$$W_{75} = 440 / q_p^{1.08} \tag{6}$$

$$W_{50} = 770 / q_p^{1.08} \tag{7}$$

The base length $t_b$ of the unit hydrograph, in days, can be estimated (Snyder, 1938) from:

$$t_b = 3 + t_p/8 \tag{8}$$

3. Unit hydrographs can be derived from the Model Hydrographs (Mitchell, 1972). Model hydrographs are developed from a dimensionless translation hydrograph, having a base time of T hours, routed through reservoir storage $S = kO^x$. Thus, the models fall into two distinct classes: (1) those for which the value of x is unity, and (2) those for which the value of x is other than unity. Mitchell describes methods of determining the hydrograph

characteristics, T, k, and x, both from observed hydrographs and from the physical characteristics of the drainage basin.

4. In 1945, Clark suggested the derivation of a unit hydrograph by routing the time-area diagram of a basin through storages such that S = kQ. The difficulty lies in estimating the time base of the time-area-diagram and the routing constant k, Clark (1945) suggested that k, in hours, can be estimated from:

$$k = cL/\sqrt{S} \tag{9}$$

in which L is the length of mainstream in miles, S is the main channel slope, and c varies from 0.8 to 2.2.

## Objectives of This Study

Unit-hydrograph procedures presently in use yield unit hydrographs (from analyses of storms and flood hydrographs or from synthetic methods) which may be suitable for deriving 2- to 5-yr or 10-yr floods because of the averaging processes inherent in these procedures. For evaluation of the adequacy of spillway capacity for dam safety, unit hydrographs suitable for deriving 100-yr flood and probable maximum flood (PMF) hydrographs are needed. Notwithstanding the principle of linearity of the unit hydrograph, it is common knowledge that generally the unit hydrographs derived from very high floods yield higher peaks and shorter times to the peak than those derived from small- to medium-size floods, although the degree of increase in peak and decrease in time to peak varies from basin to basin and region to region, depending on the physiographic, channel, and basin factors. One objective of this study is to derive unit hydrographs suitable for developing 100-yr flood hydrographs. It is assumed that if the probable maximum flood remains within the well-defined floodplain, the unit hydrograph derived for developing a 100-yr flood hydrograph will also be satisfactory for developing a PMF hydrograph, because the portion of flood discharge carried by the bankfull channel section is quite small in comparison with the 100-yr flood.

Because of the errors associated with estimation of linear storage routing coefficients and time base of the area-time-diagrams, an approach similar to that of Snyder is considered in this study. However, Snyder's equations need to be tested and perhaps drastically modified for streams in Illinois. Not only the information on the unit hydrograph widths at 75, 50, and 25 percent of peak discharge, but also the time to these discharges from the beginning of the unit hydrograph, need to be known for better definition of the unit hydrograph. Obviously, the time base of the unit hydrograph given by equation 8 is top long for small drainage basins. The ratio of $t_p$ to $t_r$ is given a constant value of 5.5, whereas this value depends on drainage area and perhaps on other factors.

In brief, the objectives of this study are to derive a sufficient number of unit hydrograph parameters for satisfactorily defining unit hydrographs suitable for determining 100-yr flood hydrographs (and PMF hydrographs) from basin factors such as drainage area, main channel length, and main channel slope for watersheds in a homogeneous region, and to divide the state into homogeneous regions in terms of similar hydrologic response to imposed storm inputs.

## Acknowledgments

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## DERIVATION AND REGIONALIZATION OF UNIT HYDROGRAPH PARAMETERS

There are about 150 gaging stations, varying in drainage area from less than 1 to about 340 square miles, for which the USGS has continuous stage hydrographs (or, for some basins, hourly discharges) for a period of 4 to 40 years. Stage hydrographs for the highest 6 to 7 floods (or fewer if sufficient data were not available) at each of these stations were obtained from the Champaign office of the USGS. The annual stage hydrographs containing the flood/floods of interest helped in the selection of about 4 well-defined and sharp-peaked hydrographs with low baseflow. In general, the drainage basins with areas exceeding 340 square miles were not considered because none of the non-federal dams in Illinois impound water from more than that drainage area.

### Methodology for Deriving Unit Hydrographs

The methodology, detailed herein for one basin, was applied to all the basins considered in this study.

1) Stage hydrographs for 6 to 7 floods were converted to discharge hydrographs with the appropriate rating tables. The number of discharge values, spaced at equal time intervals, varied from about 40 to 100.

2) For each hydrograph, hourly and daily rainfall, recorded at raingage stations in and around the basins, were tabulated for the storm causing the flood. The daily rainfall values, for 10 days prior to the storm and 5 days after it, were analyzed to define the baseflow separation satisfactorily as well as to modify the falling limb of the hydrograph slightly if some small rainfall (after the major storm) interfered with the usual flow recession.

3) On the basis of the information developed above, 3 to 4 flood hydrographs were selected which were well-defined, were sharp-peaked, and had low baseflow, and for which the temporal and spatial distribution of rainfall over the basin was relatively uniform.

4) The baseflow was approximated by a straight line with an upward trend from the beginning of surface runoff to its end.

5) The surface runoff hydrograph ordinates (obtained by subtracting the baseflow from the total flow) were tabulated and stored in the computer. The duration of effective rainfall was estimated from the basin hyetograph.

6) A computer program calculated the unit hydrograph and the S-curve with duration of effective rainfall determined in step 5, as well as with 2 durations somewhat higher and 2 durations somewhat lower than the effective rainfall duration. The resulting unit hydrographs and S-curves were printed.

7) A suitable unit-hydrograph duration was selected from the information obtained in step 6; the selection was based primarily on closeness to duration determined in step 5 and the smoothness of S-curves derived by assuming shorter or longer durations. The S-curve usually becomes smoother with smaller durations, but some unevenness in the S-curve developed from actual data is always expected because of nonuniformity of rainfall and errors in baseflow separation.

8) Unit hydrographs for the 4 flood events, as obtained in step 7, were examined to determine a suitable duration for such high floods. All 4 unit hydrographs were transformed to unit hydrographs with this suitable duration as well as with 2 somewhat higher and 2 somewhat lower durations. The use of different durations helped in defining the rate of change in the unit hydrograph peak with a small change in duration. It also helped in

defining such changes in time to the peak and in time to various percent flows, both on the rising and falling limb of the unit hydrograph. Because of the selection of high flood events, the effective rainfall duration is assumed to correspond to critical or standard duration when the flood hydrographs have sharp, well-defined peaks.

9) The unit hydrograph peaks were plotted with respect to the recurrence interval of the floods (from which they were derived) to discern any trend of increase in peak with the recurrence interval. Generally, a trend (insignificant to significant) was observed up to about a 40- or 50-year recurrence interval. Perhaps most of the flood flow is carried by the floodplain for such discharges and higher discharges, and this may lead to a quasi-linearity of the basin response for very high floods if the flood flow remains within the well-defined floodplain. The expected unit-hydrograph peak and time to the peak for a 100-year recurrence interval flood were estimated.

10) The final unit hydrograph, suitable for developing a 100-year flood hydrograph and a probable maximum flood (PMF) hydrograph with the expected peak and time to peak, was drawn, conforming to the general shape of the 4 unit hydrographs and with runoff equal to 1 inch.

11) The following unit hydrograph parameters (shown in figure 1) were estimated.

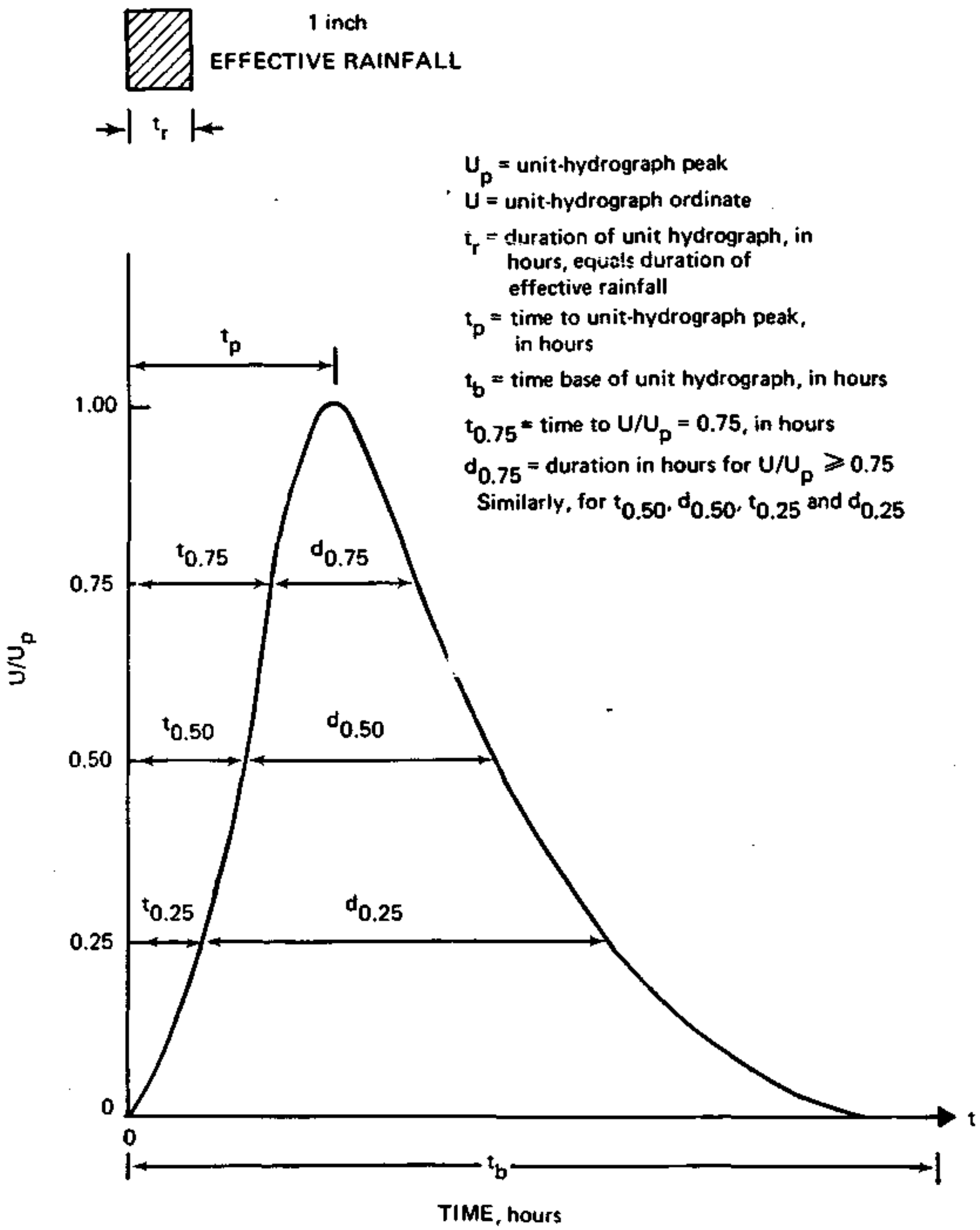
$t_r$ = duration of effective rainfall or of unit hydrograph, hours

$U_p$ = peak discharge, cfs

$t_{.25}$ = time to 0.25 $U_p$, hours

$t_{.50}$ = time to 0.50 $U_p$, hours

$t_{.75}$ = time to 0.75 $U_p$, hours




**SCHEMATIC DIAGRAM**

Figure 1. Unit hydrograph parameters — definition sketch

$t_p$ = time to peak, hours

$d_{.75}$ = unit hydrograph width at 0.75 $U_p$, hours

$d_{.50}$ = unit hydrograph width at 0.50 $U_p$, hours

$d_{.25}$ = unit hydrograph width at 0.25 $U_p$, hours

$t_b$ = time base of unit hydrograph, hours

In addition, the value of a was computed which gives the rate of increase/decrease in $U_p$ with a small decrease/increase in $t_r$, in cfs per hour.

Unit hydrograph parameters were developed for 131 basins listed under regions 1 through 8 in the latter part of this report.

Illustration

The basin of Hickory Creek above Lake Bloomington will be used as an illustration in order to describe briefly some of the results from the methodology used for deriving unit hydrographs. Pertinent data for the basin are:

| | |
|---|---|
| USGS gaging station number | 05 565000 |
| Drainage area, square miles | 9.81 |
| Main-channel length, miles | 6.74 |
| Main channel slope, ft/mi | 11.88 |
| Flow record | 1939-1959 |
| Annual maxima, cfs (year) | 1690 (1951), 1460 (1943), 1050 (1944), |
| | 930 (1953), 890 (1946), 855 (1950), |
| | 820 (1957), 680 (1945), 680 (1947), |

The stage hydrographs and the storms associated with the top 8 floods were examined to select 4 flood events such that their flood hydrographs (obtained by transforming the stage hydrographs with the rating tables) were well-defined, were sharp-peaked, and had low baseflow. After the baseflow separation, the unit hydrographs and S-curves were derived for each of the 4 events. The suitable unit hydrograph durations selected in step 7, along with some other relevant information, are given below:

| Date | $t_r$ | $t_p$ | $t_b$ | SRO | $Q_s$ | $U_p$ | T |
|---|---|---|---|---|---|---|---|
| 04.22.44 | 1.00 | 4.5 | 21.0 | 1.08 | 1037 | 957 | 7.3 |
| 04.25.50 | 2.00 | 5.0 | 29.0 | 0.95 | 783 | 828 | 3.7 |
| 07.09.51 | 1.25 | 2.5 | 27.0 | 1.55 | 1667 | 1075 | 22.0 |
| 07.05.53 | 1.25 | 3.0 | 30.0 | 1.08 | 923 | 855 | 5.5 |

Date refers to the day the observed flood peak occurred; $t_r$, $t_p$, and $t_b$ are, respectively, the duration of effective rainfall, time to the peak of unit hydrograph, and time base of the unit hydrograph, in hours; SRO denotes the surface runoff, in inches; $Q_s$ is the peak of surface runoff hydrograph in cfs; $U_p$ is the unit hydrograph peak, in cfs; and T is the recurrence interval, in years, obtained from $T=(n+1)/m$ in which n is the number of years of record and m is the rank when floods are arranged in a descending order of magnitude.

Unit hydrographs of the 4 flood events were examined to determine a suitable duration for use with high-flood hydrographs. A duration of 1.25 hours was selected. Unit hydrographs of 1.25-hour duration were obtained for all 4 events with the S-curve method from the unit hydrographs obtained earlier. These are drawn in figure 2. Unit hydrographs of somewhat lower and higher durations were also derived to determine the effect of change in $t_r$ on other unit hydrograph parameters. The final unit hydrograph (see step 10), with the expected peak and time to the peak, is drawn in figure 2.

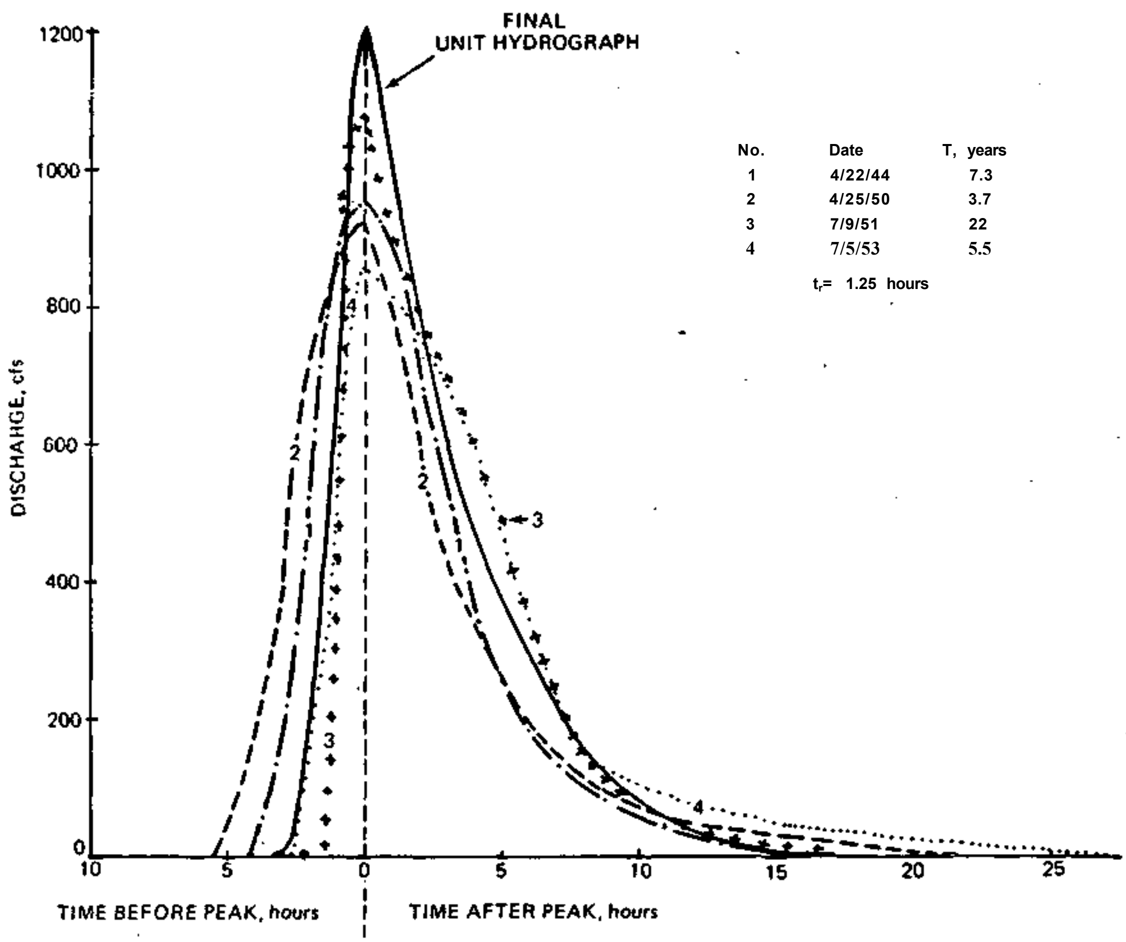



Figure 2. Unit hydrographs for Hickory Creek above Lake Bloomington

This unit hydrograph is considered suitable for deriving a 100-year and PMF hydrograph.

The rate of change in unit hydrograph peak flow for a small change in the unit hydrograph duration is given by

$$-a = dU_p/dt_r \tag{1}$$

or

$$U_{pR} = U_p - a(t_R - t_r) \tag{2}$$

in which $t_R$ refers to the new duration and a is positive. Thus, $U_{pR} < U_p$ if $t_R > t_r$, and vice versa.

The unit hydrograph parameters obtained from figure 2 are:

$t_r$ = 1.25 hours

$U_p$ = 1200 cfs

$t_{.25}$ = 1.75 hours

$t_{.50}$ = 2.15 hours

$t_{.75}$ = 2.60 hours

$t_p$ = 3.50 hours

$d_{.75}$ = 2.50 hours

$d_{.50}$ = 4.45 hours

$d_{.25}$ = 7.60 hours

$t_b$ = 18.50 hours

a = 120 cfs/hour

Regionalization of Unit-Hydrograph Parameters

The state was divided into 12 regions, demarcated on the basis of physiography (Leighton et al, 1948), model flow duration (Singh, 1971), and hydrologic and climatologic homogeneity. Regression analyses with each of the unit hydrograph parameters as a dependent variable and one or more of the basin factors (A, L, and S) as independent variables were made for the basins in each of these regions. The basins from adjacent regions were added to a region or transferred from a region to another region in a systematic way so as to obtain the minimum number of regions, providing maximum homogeneity of unit hydrograph relations for the basins within each region. In these analyses, a small time shift in the beginning of the unit hydrographs of some basins significantly improved the correlations between unit hydrograph parameters and basin factors. This small shift is attributed to imprecise information on the exact time of beginning of rainfall excess or effective rainfall. As a result of stepwise multiple correlations for each of the parameter sets from about 200 combinations of basins, the state was divided into 8 regions, as shown in figure 3. The number of study basins in each region are:

| Region | Number of basins |
|---|---|
| 1 | 15 |
| 2 | 20 |
| 3 | 11 |
| 4 | 12 |
| 5 | 26 |
| 6 | 11 |
| 7 | 19 |
| 8 | 17. |

The effect of using a unit hydrograph duration $t_R$, rather than the standard duration $t_r$, on the values of various unit hydrograph parameters

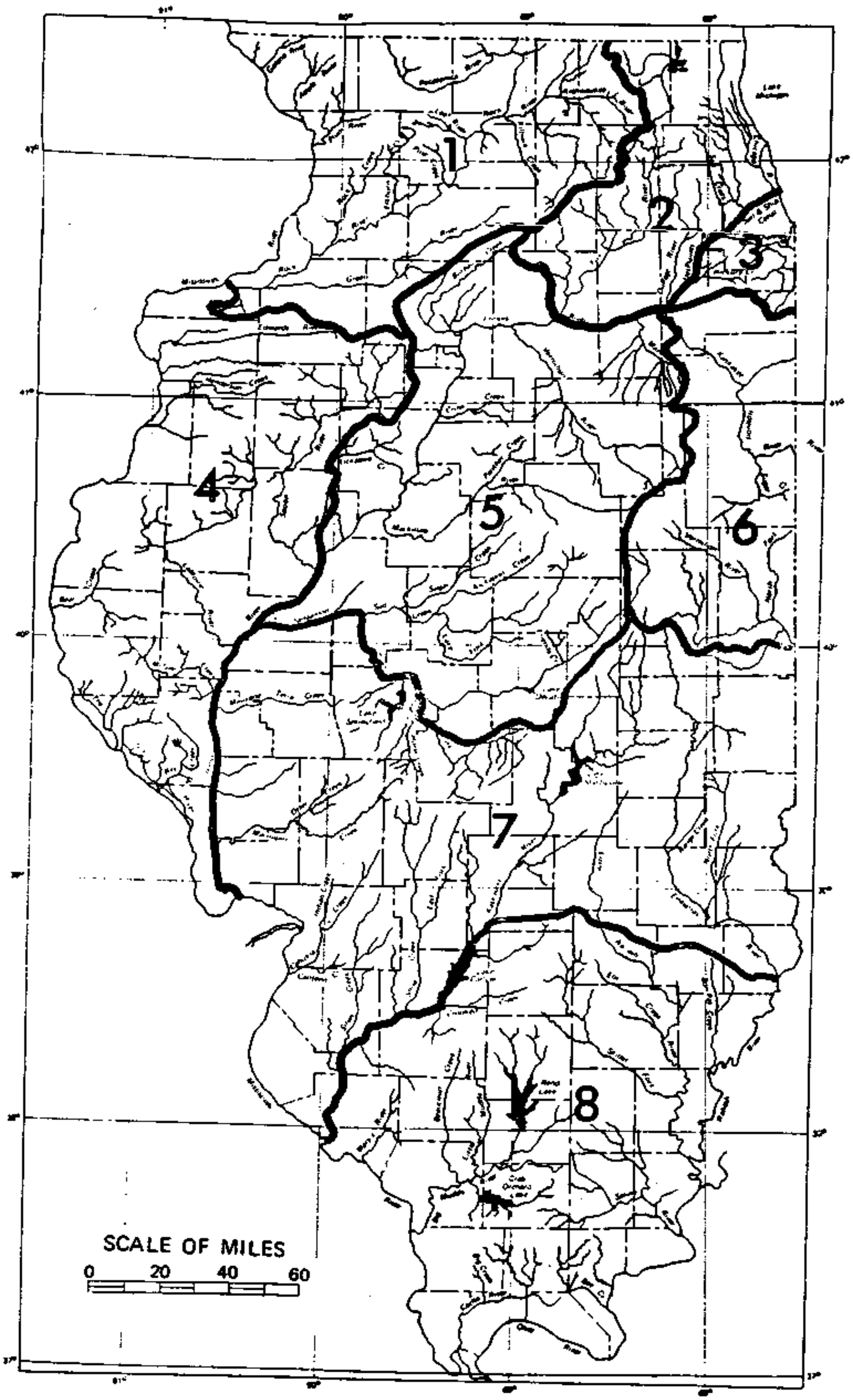



Figure 3. Regions for determining unit hydrograph parameters

is generalized by the following equations on the basis of evaluations made in this study.

$$U_{pR} = U_p - a(t_R - t_r) \tag{3}$$

$$t_{.25R} = t_{.25} + 0.5(t_R - t_r) \tag{4}$$

$$t_{.50R} = t_{.50} + 0.5(t_R - t_r) \tag{5}$$

$$t_{.75R} = t_{.75} + 0.5(t_R - t_r) \tag{6}$$

$$t_{pR} = t_p + 0.5(t_R - t_r) \tag{7}$$

$$d_{.75R} = d_{.75} + 0.5(t_R - t_r) \tag{8}$$

$$d_{.50R} = d_{.50} + 0.75(t_R - t_r) \tag{9}$$

$$d_{.25R} = d_{.25} + (t_R - t_r) \tag{10}$$

$$t_{bR} = t_b + (t_R - t_r) \tag{11}$$

In the above equations, $t_R$ is only slightly higher or lower than $t_r$. The equations serve the purpose of adjusting the parameters for a change in $t_r$ to a desirable value of $t_R$ from the consideration of a satisfactory time interval between the unit hydrograph ordinates; e.g., for $t_r = 2.76$, a $t_R$ of 3.0 may be more suitable, and for $t_r = 0.43$, a $t_R$ of 0.50 may be more suitable.

The basin factors (A, L, and S) are defined as follows:

A = drainage area, in square miles, above the gaging station, as shown in the latest USGS streamflow reports

L = main channel length, in miles, from the gaging station to the basin divide as measured on topographic maps

S = main channel slope, in feet per mile, determined from elevations at 10 and 85 percent of the distance along the main channel from the gaging station to the basin divide

The following information is provided for each of the 8 regions:

1) Number of basins, stream and gaging station, USGS number, drainage area, and length and slope of main channel.

2) Simple regression equations with log L and log S as dependent variables and log A as an independent variable; the standard error of estimate, $S_e$; simple correlation coefficient, r; multiple correlation coefficient, R; sum of the squares of differences between the logarithms of given and fitted values of L and S with the regression equations, $\sum\Delta^2$.

3) Derived unit hydrograph parameters: $t_r$, $t_p$, $U_p$, $t_{.75}$, $d_{.75}$, $t_{.50}$, $d_{.50}$, $t_{.25}$, $d_{.25}$, $t_b$, and a for all the basins; and results of stepwise multiple regressions with log $t_r$ and log a as dependent variables and A, L, and S as independent variables.

4) Modified unit hydrograph parameters for the fitted $t_r$ and a values obtained with equations 3 through 11 for all basins in a region.

5) Most significant regression equations, with logarithms of modified unit hydrograph parameters as dependent variables and logarithms of one or more of the basin factors as independent variables, together with values of $S_e$ and correlation coefficient r or R.

6) A summary of basins with fitted $U_p$ within ± 10 and ± 25 percent of derived $U_p$ (after modification of $t_r$), and any basins with more than ± 25 percent variation.

## REGION 1

The rivers, streams and tributaries included in this region are shown in figure 4, together with the location of the 15 gaging stations used for deriving the unit-hydrograph parameters. These gaging stations; their USGS number; drainage area, A, above the gaging station; main-channel length, L; and main-channel slope, S; are given in Table 1A.

*Basin Factors.* Simple correlation with log A as an independent variable and log L or log S as a dependent variable yields the following:

$$\log L = 0.263 + 0.539 \log A \tag{1}$$

$$(S_e = 0.082;\ r = 0.993;\ \Sigma\Delta^2 = 0.088)$$

$$\log S = 1.749 - 0.464 \log A \tag{2}$$

$$(S_e = 0.206;\ r = 0.947;\ \Sigma\Delta^2 = 0.552)$$

About one-half of $\sum\Delta^2$ ($\Delta^2$ is the square of the difference between the logarithms of given and fitted values of the independent variable) for the relation expressed by equation 1 comes from basins 12 and 14. More than one-half of $\sum\Delta^2$ for the relation given by equation 2 comes from basins 1 and 2. No basins yield values of L from equation 1 that exceed by more than 50 percent the corresponding values given in Table 1A. However, the values of S fitted according to equation 2 are more than 50 percent lower for basins 1 and 2 and more than 50 percent higher for basins 7, 8 and 15 than the corresponding values given in Table 1A. Both L and A, and S and A are highly correlated.

*Derived Unit-Hydrograph Parameters.* The derived unit-hydrograph parameters at each of the 15 gaging stations are given in Table 1B. The step-wise multiple correlation analyses yielded the following results:

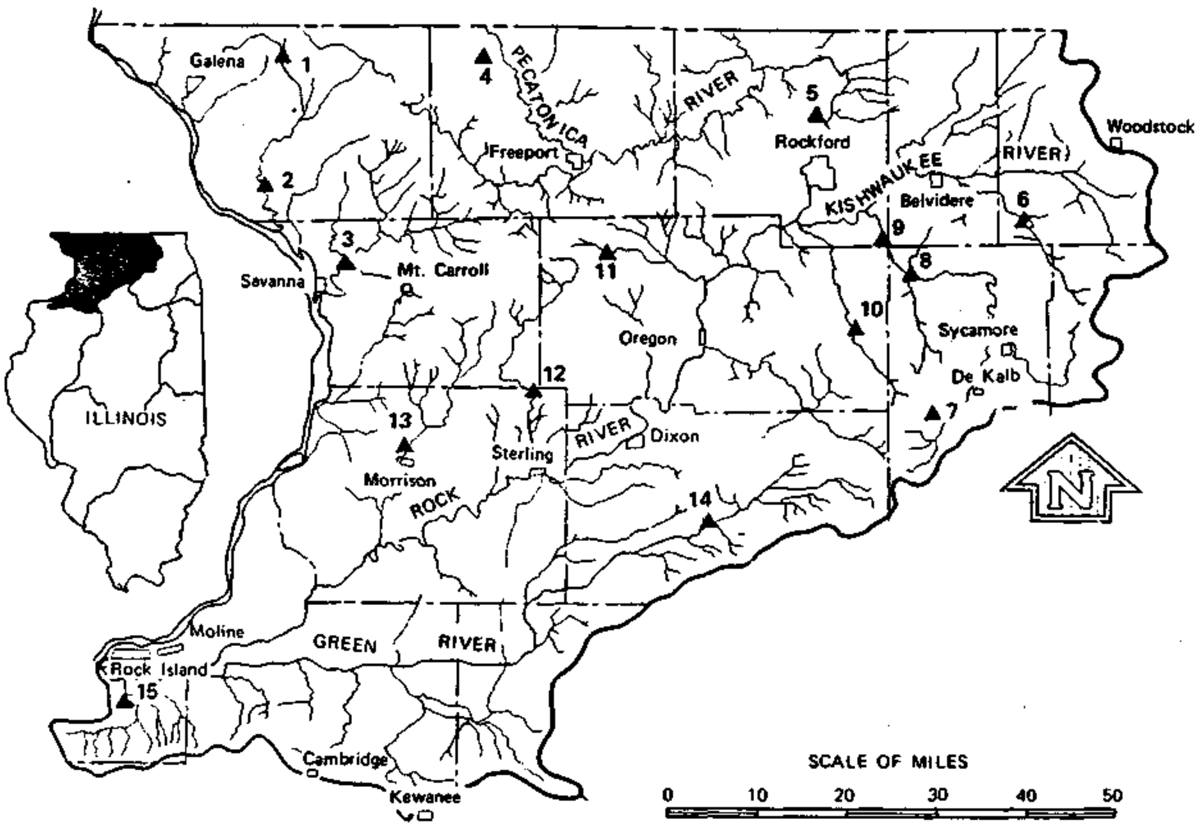



Figure 4. Study basins in region 1

$$\log t_r = -0.418 + 0.415 \log A \qquad (3a)$$
$$(S_e = 0.060;\ r = 0.994)$$

$$\log t_r = -0.305 + 0.385 \log A - 0.065 \log S \qquad (3b)$$
$$(S_e = 0.061;\ R = 0.994)$$

$$\log t_r = -0.298 + 0.395 \log A - 0.021 \log L - 0.065 \log S \qquad (3c)$$
$$(S_e = 0.064;\ R = 0.994)$$

$$\log a = 1.803 + 0.246 \log S \qquad (4a)$$
$$(S_e = 0.050;\ r = 0.954)$$

$$\log a = 1.888 - 0.039 \log L + 0.205 \log S \qquad (4b)$$
$$(S_e = 0.051;\ R = 0.955)$$

$$\log a = 1.898 - 0.070 \log A - 0.157 \log L + 0.217 \log S \qquad (4c)$$
$$(S_e = 0.052;\ R = 0.957)$$

Equations 3a and 4a have been used for computing the fitted $t_r$ and a, i.e., $t_r'$ and a' values.

*Modified Unit-Hydvograph Parameters.* With the fitted values of $t_r$ and a, the remaining 9 unit-hydrograph parameters are modified for any difference between the derived and fitted values of the two parameters. The values of $t_r'$ and a' and 9 modified parameters are given in Table 1C. The significant regression equations obtained with the step-wise multiple correlation analyses applied to the unit-hydrograph parameter as a dependent variable and the basin factors as the independent variables are as follows (the $S_e$ and R refer to the estimate of standard error and the multiple correlation coefficient from the regression between log-transformed variables, respectively):

$$t_r' = 0.382\ A^{0.415} \qquad (5)$$

$$a' = 63.56\ S^{0.246} \qquad (6)$$

$$t_p = 1.329\ A^{0.788}\ L^{-0.530} \qquad (7)$$
$$(S_e = 0.036;\ R = 0.999)$$

$$U_p = 118.7\ A^{0.618}\ S^{0.393} \tag{8}$$
$$(S_e = 0.039;\ R = 0.998)$$

$$t_{.75} = 1.240\ A^{0.970}\ L^{-0.904} \tag{9}$$
$$(S_e = 0.044;\ R = 0.998)$$

$$d_{.75} = 1.658\ A^{0.426}\ S^{-0.266} \tag{10}$$
$$(S_e = 0.071;\ R = 0.996)$$

$$t_{.50} = 1.140\ A^{1.044}\ L^{-1.071} \tag{11}$$
$$(S_e = 0.055;\ R = 0.997)$$

$$d_{.50} = 3.565\ A^{0.402}\ S^{-0.336} \tag{12}$$
$$(S_e = 0.050;\ R = 0.998)$$

$$t_{.25} = 0.877\ A^{1.082}\ L^{-1.181} \tag{13}$$
$$(S_e = 0.075;\ R = 0.993)$$

$$d_{.25} = 7.089\ A^{0.387}\ S^{-0.383} \tag{14}$$
$$(S_e = 0.039;\ R = 0.999)$$

$$t_b = 16.87\ A^{0.372}\ S^{-0.326} \tag{15}$$
$$(S_e = 0.062;\ R = 0.996)$$

*Fitted Unit-Hydrograph Parameters.* These parameters, obtained from equations 5 through 15, are given in Table 1D. All the "t" equations use A and L, and all the "d" equations use A and S as independent variables.

The 15 basins are summarized below in terms of the derived and fitted values of the unit-hydrograph peak from Table 1C and 1D, respectively.

fitted $U_p$ within ± 10% of derived $U_p$ 12 basins

fitted $U_p$ within ± 25% of derived $U_p$ 15 basins

TABLE 1. Unit Hydrograph Parameters For Region 1

A. Basin Factors

| No. | Stream and Gaging Station | USGS No. | Area | Length | Slope |
|---|---|---|---|---|---|
| 1 | Mill Creek Tributary near Scales Mound | 05418800 | .86 | 1.51 | 157.87 |
| 2 | Apple River near Hanover | 05419000 | 247.00 | 36.91 | 10.93 |
| 3 | Plum River below Carroll Cr. nr. Savanna | 05420000 | 230.00 | 31.38 | 6.55 |
| 4 | Cedar Creek near Winslow | 05435000 | 1.31 | 2.10 | 40.90 |
| 5 | Rock River Tributary near Rockton | 05437600 | 2.21 | 2.53 | 40.26 |
| 6 | Coon Creek at Riley | 05438250 | 85.10 | 16.45 | 5.72 |
| 7 | M. Br. of S. Br. Kishwaukee R. nr. Malta | 05438850 | 1.67 | 2.60 | 28.72 |
| 8 | S. Br. Kishwaukee River near Fairdale | 05439500 | 387.00 | 40.29 | 2.27 |
| 9 | S. Br. Kishwaukee R. Trib. nr. Irene | 05439550 | 1.71 | 2.22 | 53.75 |
| 10 | Killbuck Creek near Monroe Center | 05440500 | 117.00 | 26.80 | 6.34 |
| 11 | Leaf River Tributary near Forreston | 05440900 | .15 | .81 | 144.14 |
| 12 | Elkhorn Creek near Penrose | 05444000 | 146.00 | 38.97 | 4.28 |
| 13 | Rock Creek near Morrison | 05445500 | 158.00 | 36.68 | 3.91 |
| 14 | Green River at Amboy | 05447000 | 201.00 | 23.63 | 3,85 |
| 15 | Sand Creek near Milan | 05448050 | ,22 | 76 | 67.06 |

B. Derived Unit-Hydrograph Parameters

| No. | $t_r$ | $t_p$ | $U_p$ | $t_{.75}$ | $d_{.75}$ | $t_{.50}$ | $d_{.50}$ | $t_{.25}$ | $d_{.25}$ | $t_b$ | a |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | .34 | .80 | 850 | .64 | .38 | .59 | .54 | .51 | .98 | 2.51 | 240 |
| 2 | 4.00 | 15.00 | 8500 | 10.50 | 10.50 | 8.00 | 14.70 | 4.40 | 22.10 | 66.00 | 120 |
| 3 | 3.00 | 14.00 | 7600 | 11.50 | 7.50 | 9.20 | 16.00 | 6.50 | 27.70 | 70.00 | 100 |
| 4 | .33 | 1.08 | 640 | .92 | .55 | .80 | .93 | .58 | 1.67 | 5.67 | 180 |
| 5 | .50 | 1.70 | 850 | 1.20 | 1.12 | 1.03 | 1.50 | .70 | 2.37 | 6.67 | 150 |
| 6 | 3.00 | 11.50 | 3000 | 7.90 | 8.10 | 6.00 | 14.00 | 3.70 | 24.80 | 65.00 | 100 |
| 7 | .53 | 1.20 | 610 | .85 | .78 | .63 | 1.40 | .45 | 2.40 | 5.42 | 150 |
| 8 | 5.00 | 20.50 | 7000 | 14.00 | 16.00 | 11.50 | 27.70 | 8.00 | 50.00 | 102.00 | 80 |
| 9 | .50 | 1.35 | 800 | 1.00 | .70 | .78 | 1.13 | .52 | 1.80 | 5.67 | 140 |
| 10 | 3.00 | 11.00 | 4200 | 6.90 | 9.00 | 5.30 | 15.40 | 3.60 | 24.60 | 56.00 | 80 |
| 11 | .17 | .33 | 250 | .27 | .19 | .23 | .38 | .17 | .55 | 1.92 | 200 |
| 12 | 3.00 | 9.00 | 5400 | 5.40 | 8.50 | 3.80 | 13.90 | 2.30 | 24.20 | 60.00 | 100 |
| 13 | 3.00 | 11.00 | 4500 | 5.70 | 12.50 | 4.20 | 18.30 | 2.70 | 30.80 | 70.00 | 80 |
| 14 | 3.00 | 15.00 | 5400 | 11.60 | 9.60 | 9.00 | 18.80 | 6.00 | 34.00 | 80.00 | 100 |
| 15 | .25 | .50 | 225 | .34 | .33 | .29 | .48 | .21 | .79 | 2.75 | 200 |

C. Modified Unit-Hydrograph Parameters Using Fitted $t_r$ and a

| No. | $t_r'$ | $t_p$ | $U_p$ | $t_{.75}$ | $d_{.75}$ | $t_{.50}$ | $d_{.50}$ | $t_{.25}$ | $d_{.25}$ | $t_b$ | a' |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | .36 | .81 | 845 | .65 | .39 | .60 | .55 | .52 | 1.00 | 2.53 | 221 |
| 2 | 3.75 | 14.88 | 8528 | 10.38 | 10.38 | 7.88 | 14.51 | 4.28 | 21.85 | 65.75 | 115 |
| 3 | 3.64 | 14.32 | 7535 | 11.82 | 7.82 | 9.52 | 16.48 | 6.82 | 28.34 | 70.64 | 101 |
| 4 | .43 | 1.13 | 624 | .97 | .60 | .85 | 1.00 | .63 | 1.77 | 5.77 | 159 |
| 5 | .53 | 1.72 | 845 | 1.22 | 1.14 | 1.05 | 1.52 | .72 | 2.40 | 6.70 | 158 |
| 6 | 2.41 | 11.21 | 3057 | 7.61 | 7.81 | 5.71 | 13.56 | 3.41 | 24.21 | 64.41 | 98 |
| 7 | .47 | 1.17 | 618 | .82 | .75 | .60 | 1.36 | .42 | 2.34 | 5.36 | 145 |
| 8 | 4.52 | 20.26 | 7037 | 13.76 | 15.76 | 11.26 | 27.34 | 7.76 | 49.52 | 101.52 | 78 |
| 9 | .48 | 1.34 | 803 | .99 | .69 | .77 | 1.11 | .51 | 1.78 | 5.65 | 170 |
| 10 | 2.75 | 10.88 | 4224 | 6.78 | 8.88 | 5.18 | 15.21 | 3.48 | 24.35 | 55.75 | 100 |
| 11 | .17 | .33 | 249 | .27 | .19 | .23 | .38 | .17 | .55 | 1.92 | 216 |
| 12 | 3.02 | 9.01 | 5398 | 5.41 | 8.51 | 3.81 | 13.91 | 2.31 | 24.22 | 60.02 | 91 |
| 13 | 3.12 | 11.06 | 4489 | 5.76 | 12.56 | 4.26 | 18.39 | 2.76 | 30.92 | 70.12 | 89 |
| 14 | 3.45 | 15.22 | 5360 | 11.82 | 9.82 | 9.22 | 19.13 | 6.22 | 34.45 | 80.45 | 89 |
| 15 | .20 | .48 | 233 | .32 | .31 | .27 | .45 | .19 | .74 | 2.70 | 179 |

D. Fitted Unit-Hydrograph Parameters

| No. | $t_r$ | $t_p$ | $U_p$ | $t_{.75}$ | $d_{.75}$ | $t_{.50}$ | $d_{.50}$ | $t_{.25}$ | $d_{.25}$ | $t_b$ | a |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | .36 | .95 | 790 | .74 | .41 | .63 | .61 | .46 | .96 | 3.07 | 221 |
| 2 | 3.75 | 15.06 | 9132 | 9.94 | 9.20 | 7.53 | 14.60 | 4.79 | 23.95 | 59.98 | 115 |
| 3 | 3.64 | 15.51 | 7145 | 10.74 | 10.22 | 8.32 | 16.86 | 5.37 | 28.35 | 69.02 | 101 |
| 4 | .43 | 1.11 | 603 | .82 | .69 | .68 | 1.14 | .49 | 1.90 | 5.57 | 159 |
| 5 | .53 | 1.52 | 827 | 1.16 | .87 | .97 | 1.42 | .69 | 2.34 | 6.80 | 158 |
| 6 | 2.41 | 9.98 | 3666 | 7.34 | 6.93 | 5.88 | 11.83 | 3.93 | 20.32 | 49.85 | 98 |
| 7 | .47 | 1.20 | 609 | .86 | .85 | .70 | 1.42 | .49 | 2.39 | 6.84 | 145 |
| 8 | 4.52 | 20.47 | 6499 | 14.20 | 16.90 | 10.96 | 29.66 | 7.02 | 52.02 | 118.28 | 78 |
| 9 | .48 | 1.33 | 791 | 1.01 | .72 | .85 | 1.16 | .61 | 1.90 | 5.62 | 170 |
| 10 | 2.75 | 9.90 | 4647 | 6.43 | 7.73 | 4.86 | 12.99 | 3.11 | 22.09 | 54.26 | 100 |
| 11 | .17 | .33 | 259 | .24 | .20 | .20 | .31 | .14 | .51 | 1.65 | 216 |
| 12 | 3.02 | 9.67 | 4566 | 5.68 | 9.43 | 4.10 | 16.20 | 2.54 | 27.98 | 66.96 | 91 |
| 13 | 3.12 | 10.62 | 4627 | 6.48 | 9.99 | 4.75 | 17.24 | 2.97 | 29.86 | 71.02 | 89 |
| 14 | 3.45 | 16.22 | 5336 | 12.18 | 11.11 | 9.79 | 19.09 | 6.49 | 32.97 | 78.06 | 89 |
| 15 | .20 | .47 | 243 | .37 | .28 | .32 | .47 | .24 | .79 | 2.44 | 179 |

## REGION 2

The rivers, streams and tributaries included in this region are shown in figure 5, together with the location of the 20 gaging stations used for deriving the unit-hydrograph parameters. These gaging stations; their USGS number; drainage area, A, above the gaging station; main-channel length, L; and main-channel slope, S; are given in Table 2A.

*Basin Factors.* Simple correlation with log A as an independent variable and log L or log S as a dependent variable yields the following:

$$\log L = 0.280 + 0.584 \log A \qquad (1)$$

$$(S_e = 0.084;\ r = 0.986;\ \Sigma\Delta^2 = 0.127)$$

$$\log S = 1.487 - 0.413 \log A \qquad (2)$$

$$(S_e = 0.256;\ r = 0.808;\ \Sigma\Delta^2 = 1.187)$$

More than one-half of $\sum\Delta^2$ ($\Delta^2$ is the square of the difference between the logarithms of given and fitted values of the independent variable) for the relation expressed by equation 1 comes from basins 8, 18 and 19. More than one-half of $\sum\Delta^2$ for the relation given by equation 2 comes from basins 8, 10, 14 and 18. No basins yield values of L from equation 1 that exceed by more than 50 percent the corresponding values given in Table 2A. However, the values of S fitted according to equation 2 are more than 50 percent lower for basins 14, 18 and 20 and more than 50 percent higher for basins 5, 6, 8, 9, 10 and 11 than the corresponding values given in Table 2A. This indicates that L and A are much more highly correlated than S and A.

*Derived Unit-Hydrograph Parameters.* The derived unit-hydrograph parameters at each of the 20 gaging stations are given in Table 2B. The step-wise multiple correlation analyses yielded the following results:

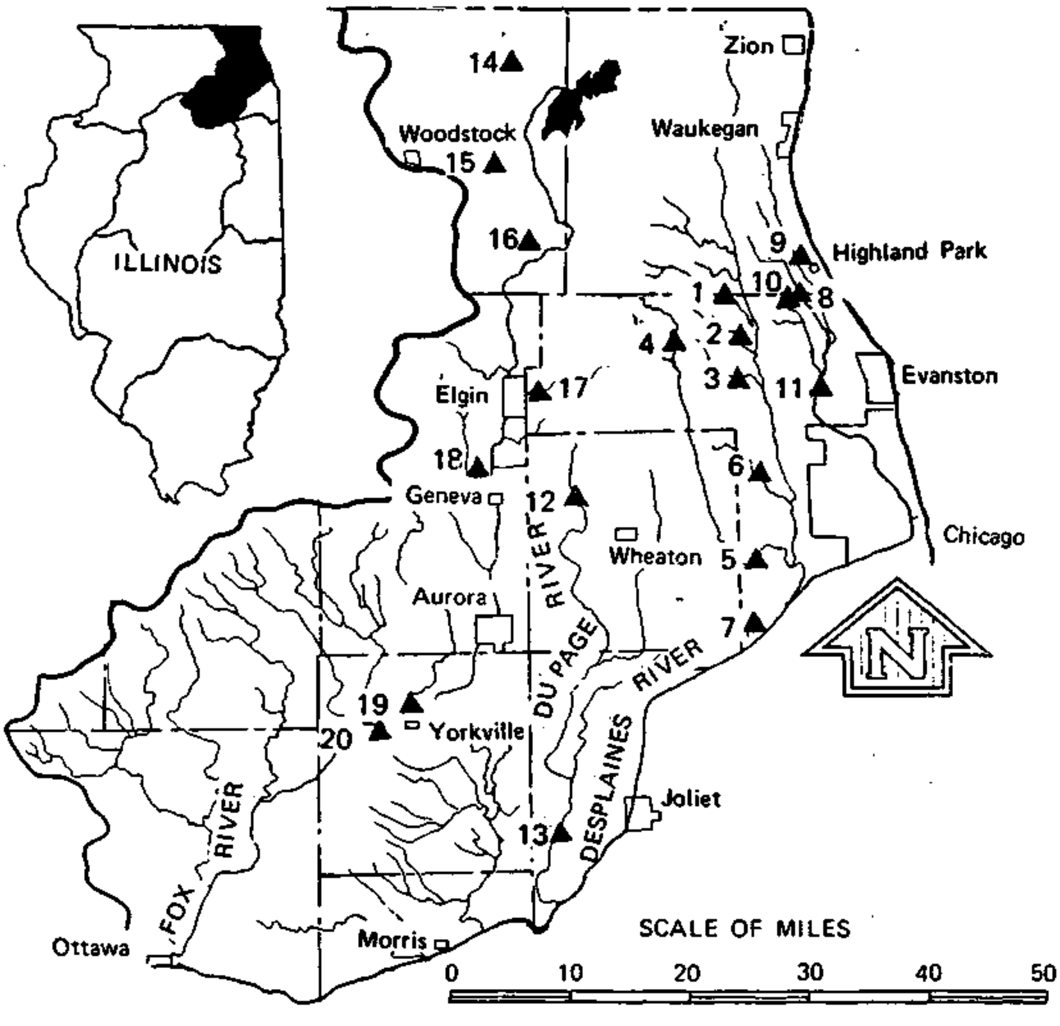



Figure 5. Study basins in region 2

$$\log t_r = -0.202 + 0.435 \log A \qquad (3a)$$

$$(S_e = 0.058;\ r = 0.988)$$

$$\log t_r = -0.110 + 0.409 \log A - 0.062 \log S \qquad (3b)$$

$$(S_e = 0.057;\ R = 0.989)$$

$$\log t_r = -0.093 + 0.424 \log A - 0.029 \log L - 0.068 \log S \qquad (3c)$$

$$(S_e = 0.059;\ R = 0.989)$$

$$\log a = 1.440 + 0.327 \log S \qquad (4a)$$

$$(S_e = 0.102;\ r = 0.813)$$

$$\log a = 1.608 - 0.085 \log L + 0.242 \log S \qquad (4b)$$

$$(S_e = 0.103;\ R = 0.823)$$

$$\log a = 2.265 + 0.670 \log A - 1.360 \log L + 0.028 \log S \qquad (4c)$$

$$(S_e = 0.060;\ R = 0.947)$$

Equations 3a and 4c have been used for computing the fitted $t_r$ and a, i.e., $t_r'$ and a' values.

*Modified Unit-Hydrograph Parameters:* With the fitted values of $t_r$ and a, the remaining 9 unit-hydrograph parameters are modified for any difference between the derived and fitted values of the two parameters. The values of $t_r'$ and a' and 9 modified parameters are given in Table 2C. The significant regression equations obtained with the step-wise multiple correlation analyses applied to the unit-hydrograph parameter as a dependent variable and the basin factors as the independent variables are as follows (the $S_e$ and R refer to the estimate of standard error and the multiple correlation coefficient from the regression between log-transformed variables, respectively):

$$t_r' = 0.628\ A^{0.435} \qquad (5)$$

$$a' = 184.0\ A^{0.670}\ L^{-1.360}\ S^{0.028} \qquad (6)$$

$$t_p = 3.000\ A^{0.421}\ S^{-0.075} \qquad (7)$$

$$(S_e = 0.044;\ R = 0.994)$$

$$U_p = 360.0\ A^{0.867}\ L^{-0.708} \tag{8}$$
$$(S_e = 0.086;\ R = 0.978)$$

$$t_{.75} = 1.605\ A^{0.456} \tag{9}$$
$$(S_e = 0.051;\ r = 0.992)$$

$$d_{.75} = 1.066\ A^{0.295}\ L^{0.416} \tag{10}$$
$$(S_e = 0.058;\ R = 0.993)$$

$$t_{.50} = 1.333\ A^{0.444} \tag{11}$$
$$(S_e = 0.051;\ r = 0.991)$$

$$d_{.50} = 1.558\ A^{0.187}\ L^{0.617} \tag{12}$$
$$(S_e = 0.063;\ R = 0.992)$$

$$t_{.25} = 0.900\ A^{0.442} \tag{13}$$
$$(S_e = 0.051;\ r = 0.991)$$

$$d_{.25} = 2.143\ L^{0.943} \tag{14}$$
$$(S_e = 0.095;\ R = 0.981)$$

$$t_b = 6.211\ L^{0.855} \tag{15}$$
$$(S_e = 0.131;\ R = 0.967)$$

*Fitted Unit-Hydrograph Parameters.* These parameters, obtained from equations 5 through 15, are given in Table 2D.

The 20 basins are summarized below in terms of the derived and fitted values of the unit-hydrograph peak from Table 2C and 2D, respectively.

fitted $U_p$ within ± 10% of derived $U_p$ 6 basins

fitted $U_p$ within ± 25% of derived $U_p$ 17 basins

remaining 3 basins

| number | fitted/derived $U_p$ |
|---|---|
| 4 | 1.434 |
| 8 | 1.316 |
| 13 | 0.658 |

TABLE 2. Unit-Hydrograph Parameters for Region 2

A. Basin Factors

| No. | Stream and Gaging Stations | USGS No. | Area | Length | Slope |
|---|---|---|---|---|---|
| 1 | Buffalo Creek near Wheeling | 05528500 | 19.60 | 10.89 | 15.42 |
| 2 | McDonald Creek near Mount Prospect | 05529500 | 7.93 | 7.04 | 9.66 |
| 3 | Weller Creek at Des Plaines | 05530000 | 13.20 | 7.34 | 10.60 |
| 4 | Salt Creek near Arlingron Heights | 05531000 | 32.10 | 11.30 | 13.39 |
| 5 | Salt Creek at Western Springs | 05531500 | 114.00 | 36.38 | 2.85 |
| 6 | Addison Creek near Bellwood | 05532000 | 17.90 | 8.97 | 6.21 |
| 7 | Flag Creek near Willow Springs | 05533000 | 16.50 | 9.29 | 14.04 |
| 8 | N. Br. Chicago River at Deerfield | 05534500 | 19.70 | 16.10 | 3.24 |
| 9 | Skokie River at Lake Forest | 05535000 | 13.00 | 10.29 | 5.58 |
| 10 | W. G. of N. Br. Chicago R. at N. Brook | 05535500 | 11.50 | 8.37 | 3.69 |
| 11 | North Branch Chiago River at Niles | 05536000 | 100.00 | 29.15 | 2.94 |
| 12 | W. Br. DuPage River near West Chicago | 05539900 | 28.50 | 14.06 | 6.58 |
| 13 | DuPage River at Shorewood | 05540500 | 324.00 | 52.58 | 4.38 |
| 14 | Nippersink Creek near Spring Grove | 05548280 | 192.00 | 2.15 | 7.68 |
| 15 | Boone Creek near McHenry | 05549000 | 15.50 | 8.90 | 7.34 |
| 16 | Fox River Tributary near Cary | 05549900 | .07 | .42 | 115.10 |
| 17 | Poplar Creek at Elgin | 05550500 | 35.20 | 16.43 | 9.08 |
| 18 | Ferson Creek near St. Charles | 05551200 | 51.70 | 13.45 | 13.31 |
| 19 | Blackberry Creek near Yorkville | 05551700 | 70.20 | 31.53 | 5.60 |
| 20 | Fox River Tributary No. 2 near Fox | 05551800 | .45 | 1.02 | 87.12 |

B. Derived Unit-Hydrograph Parameters

| No. | $t_r$ | $t_p$ | $U_p$ | $t_{.75}$ | $d_{.75}$ | $t_{.50}$ | $d_{.50}$ | $t_{.25}$ | $d_{.25}$ | $t_b$ | a |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.00 | 8.00 | 800 | 6.90 | 6.50 | 6.00 | 12.00 | 4.00 | 22.50 | 54.00 | 60 |
| 2 | 2.00 | 7.00 | 450 | 5.00 | 4.90 | 4.00 | 8.50 | 2.50 | 15.90 | 42.00 | 50 |
| 3 | 2.00 | 7.00 | 1000 | 4.70 | 4.90 | 4.00 | 7.60 | 2.90 | 11.60 | 32.00 | 70 |
| 4 | 3.00 | 11.00 | 900 | 8.20 | 9.10 | 6.30 | 18.20 | 3.90 | 36.00 | 70.00 | 60 |
| 5 | 4.00 | 18.00 | 2100 | 11.60 | 20.00 | 9.00 | 32.40 | 6.70 | 49.60 | 90.00 | 30 |
| 6 | 2.00 | 8.50 | 1100 | 4.90 | 5.00 | 4.30 | 8.40 | 3.60 | 13.90 | 37.50 | 70 |
| 7 | 2.00 | 7.00 | 900 | 5.00 | 5.60 | 4.20 | 9.20 | 3.30 | 16.30 | 41.00 | 80 |
| 8 | 3.00 | 9.50 | 485 | 6.70 | 8.80 | 5.10 | 16.60 | 3.00 | 37.80 | 96.00 | 35 |
| 9 | 2.00 | 9.00 | 640 | 6.00 | 6.00 | 4.50 | 12.20 | 2.50 | 21.00 | 44.00 | 40 |
| 10 | 2.00 | 7.50 | 660 | 5.10 | 5.40 | 4.00 | 9.40 | 2.50 | 15.90 | 39.50 | 60 |

B. Derived Unit-Hydrograph Parameters (continued)

| No. | $t_r$ | $t_p$ | $U_p$ | $t_{.75}$ | $d_{.75}$ | $t_{.50}$ | $d_{.50}$ | $t_{.25}$ | $d_{.25}$ | $t_b$ | a |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 11 | 4.00 | 17.00 | 2200 | 12.00 | 15.00 | 9.20 | 28.00 | 6.80 | 43.80 | 82.00 | 40 |
| 12 | 3.00 | 12.00 | 950 | 8.60 | 9.60 | 7.10 | 14.20 | 4.20 | 25.60 | 67.00 | 50 |
| 13 | 7.00 | 28.00 | 5000 | 19.90 | 21.60 | 14.30 | 37.70 | 10.40 | 58.60 | 110.00 | 50 |
| 14 | 6.00 | 28.00 | 2600 | 16.40 | 24.60 | 13.00 | 39.00 | 9.20 | 64.80 | 162.00 | 70 |
| 15 | 2.00 | 9.00 | 720 | 6.20 | 7.20 | 5.20 | 10.40 | 3.80 | 17.40 | 50.00 | 70 |
| 16 | .17 | .66 | 80 | .41 | .33 | .36 | .50 | .26 | .75 | 2.41 | 120 |
| 17 | 3.00 | 10.00 | 900 | 7.40 | 9.30 | 6.00 | 19.90 | 4.10 | 38.00 | 75.00 | 40 |
| 18 | 4.00 | 13.00 | 1500 | 10.90 | 12.00 | 8.90 | 18.30 | 4.90 | 29.40 | 76.00 | 70 |
| 19 | 4.00 | 18.00 | 1300 | 13.20 | 16.80 | 10.30 | 29.30 | 6.50 | 48.20 | 96.00 | 30 |
| 20 | .42 | 1.50 | 200 | 1.12 | .75 | .86 | 1.27 | .60 | 2.02 | 4.70 | 120 |

C. Modified Unit-Hydrograph Parameters Using Fitted $t_r$ and a

| No. | $t_r'$ | $t_p$ | $U_p$ | $t_{.75}$ | $d_{.75}$ | $t_{.50}$ | $d_{.50}$ | $t_{.25}$ | $d_{.25}$ | $t_b$ | a' |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.29 | 8.14 | 783 | 7.04 | 6.64 | 6.14 | 12.22 | 4.14 | 22.79 | 54.29 | 57 |
| 2 | 1.54 | 6.77 | 475 | 4.77 | 4.67 | 3.77 | 8.16 | 2,27 | 15.44 | 41.54 | 55 |
| 3 | 1.93 | 6.96 | 1005 | 4.66 | 4.86 | 3.96 | 7.55 | 2.86 | 11.53 | 31.93 | 74 |
| 4 | 2.84 | 10.92 | 912 | 8.12 | 9.02 | 6.22 | 18.08 | 3.82 | 35.84 | 69.84 | 75 |
| 5 | 4.93 | 18.46 | 2068 | 12.06 | 20.46 | 9.46 | 33.09 | 7.16 | 50.53 | 90.93 | 34 |
| 6 | 2.20 | 8.60 | 1086 | 5.00 | 5.10 | 4.40 | 8.55 | 3.70 | 14.10 | 37.70 | 68 |
| 7 | 2.12 | 7.06 | 892 | 5.06 | 5.66 | 4.26 | 9.29 | 3.36 | 16.42 | 41.12 | 63 |
| 8 | 2.29 | 9.15 | 507 | 6.35 | 8.45 | 4.75 | 16.07 | 2.65 | 37.09 | 95.29 | 32 |
| 9 | 1.92 | 8.96 | 643 | 5.96 | 5.96 | 4.46 | 12.14 | 2.46 | 20.92 | 43.92 | 4b |
| 10 | 1.82 | 7.41 | 670 | 5.01 | 5.31 | 3.91 | 9.26 | 2,41 | 15.72 | 39.32 | 55 |
| 11 | 4.65 | 17.33 | 2172 | 12.33 | 15.33 | 9.53 | 28.49 | 7.13 | 44.45 | 82.65 | 42 |
| 12 | 2.69 | 11.85 | 965 | 8.45 | 9.45 | 6.95 | 13.97 | 4.05 | 25.29 | 66.69 | 50 |
| 13 | 7.76 | 28.38 | 4968 | 20.28 | 21.98 | 14.68 | 38.27 | 10.78 | 59.36 | 110.76 | 42 |
| 14 | 6.18 | 28.09 | 2589 | 16.49 | 24.69 | 13.09 | 39.13 | 9.29 | 64.98 | 162.18 | 59 |
| 15 | 2.07 | 9.03 | 715 | 6.23 | 7.23 | 5.23 | 10.45 | 3.83 | 17.47 | 50.07 | 62 |
| 16 | .20 | .67 | 76 | .42 | .34 | .37 | .52 | .27 | .78 | 2.44 | 116 |
| 17 | 2.95 | 9.98 | 902 | 7.38 | 9.28 | 5.98 | 19.87 | 4.08 | 37.95 | 74.95 | 47 |
| 18 | 3.49 | 12.75 | 1541 | 10.65 | 11.75 | 8.65 | 17.92 | 4.65 | 28.89 | 75.49 | 81 |
| 19 | 3.99 | 17.99 | 1300 | 13.19 | 16.79 | 10.29 | 29.29 | 6.49 | 48.19 | 95.99 | 31 |
| 20 | .44 | 1.51 | 197 | 1.13 | .76 | .87 | 1.29 | .61 | 2.04 | 4.72 | 119 |

D. Fitted Unit-Hydrograph Parameters

| No. | $t_r$ | $t_p$ | $U_p$ | $t_{.75}$ | $d_{.75}$ | $t_{.50}$ | $d_{.50}$ | $t_{.25}$ | $d_{.25}$ | $t_b$ | a |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.29 | 8.54 | 876 | 6.23 | 6.91 | 5.00 | 11.86 | 3.35 | 20.34 | 47.88 | 57 |
| 2 | 1.54 | 6.05 | 544 | 4.13 | 4.41 | 3.34 | 7.65 | 2.25 | 13.49 | 32.97 | 55 |
| 3 | 1.93 | 7.44 | 822 | 5.20 | 5.22 | 4.19 | 8.63 | 2.82 | 14.03 | 34.17 | 74 |
| 4 | 2.84 | 10.63 | 1308 | 7.81 | 8.11 | 6.23 | 13.30 | 4.17 | 21.07 | 49.41 | 75 |
| 5 | 4.93 | 20.36 | 1716 | 13.91 | 19.15 | 10.93 | 34.68 | 7.30 | 63.41 | 134.33 | 34 |
| 6 | 2.20 | 8.81 | 928 | 5.98 | 6.20 | 4.80 | 10.34 | 3.22 | 16.95 | 40.56 | 68 |
| 7 | 2.12 | 8.00 | 844 | 5.76 | 6.15 | 4.63 | 10.41 | 3.11 | 17.52 | 41.79 | 63 |
| 8 | 2.29 | 9.63 | 667 | 6.25 | 8.14 | 5.01 | 15.10 | 3.36 | 29.41 | 66.89 | 32 |
| 9 | 1.92 | 7.76 | 638 | 5.17 | 5.98 | 4.17 | 10.60 | 2.80 | 19.29 | 45.61 | 45 |
| 10 | 1.82 | 7.60 | 664 | 4.89 | 5.29 | 3.95 | 9.12 | 2.65 | 15.88 | 38.23 | 55 |
| 11 | 4.65 | 19.22 | 1792 | 13.10 | 16.80 | 10.31 | 29.52 | 6.89 | 51.46 | 111.14 | 42 |
| 12 | 2.69 | 10.66 | 1011 | 7.39 | 8.58 | 5.90 | 14.89 | 3.96 | 25.88 | 59.57 | 50 |
| 13 | 7.76 | 30.59 | 3270 | 22.40 | 30.36 | 17.39 | 52.92 | 11.59 | 89.73 | 184.06 | 42 |
| 14 | 6.18 | 23.53 | 2943 | 17.64 | 21.21 | 13.78 | 35.43 | 9.20 | 56.44 | 120.85 | 59 |
| 15 | 2.07 | 8.18 | 824 | 5.60 | 5.93 | 4.51 | 10.02 | 3.02 | 16.82 | 40.29 | 62 |
| 16 | .20 | .69 | 66 | .48 | .34 | .41 | .55 | .28 | .94 | 2.94 | 116 |
| 17 | 2.95 | 11.38 | 1087 | 8.14 | 9.74 | 6.49 | 17.05 | 4.34 | 29.98 | 68.06 | 47 |
| 18 | 3.49 | 12.99 | 1748 | 9.70 | 10.03 | 7.69 | 16.19 | 5.15 | 24.82 | 57.35 | 81 |
| 19 | 3.99 | 15.78 | 1247 | 11.15 | 15.64 | 8.81 | 29.00 | 5.89 | 55.41 | 118.85 | 31 |
| 20 | .44 | 1.53 | 177 | 1.11 | .85 | .93 | 1.36 | .63 | 2.18 | 6.32 | 119 |

REGION 3

The rivers, streams and tributaries included in this region are shown in figure 6, together with the location of the 11 gaging stations used for deriving the unit-hydrograph parameters. These gaging stations; their USGS number; drainage area, A, above the gaging station; main-channel length, L; and main-channel slope, S; are given in Table 3A.

*Basin Factors.* Simple correlation with log A as an independent variable and log L or log S as a dependent variable yields the following:

$$\log L = 0.553 + 0.363 \log A \qquad (1)$$
$$(S_e = 0.082;\ r = 0.856;\ \Sigma\Delta^2 = 0.060)$$

$$\log S = 0.850 + 0.067 \log A \qquad (2)$$
$$(S_e = 0.211;\ r = 0.117;\ \Sigma\Delta^2 = 0.402)$$

About one-half of $\sum\Delta^2$ ($\Delta^2$ is the square of the difference between the logarithms of given and fitted values of the independent variable) for the relation expressed by equation 1 comes from basins 3 and 10. More than one-half of $\sum\Delta^2$ for the relation given by equation 2 comes from basins 1, 2 and 8, No basins yield values of L from equation 1 that exceed by more than 50 percent the corresponding values given in Table 3A. However, the values of S fitted according to equation 2 are more than 50 percent lower for basin 1 and more than 50 percent higher for basin 8 than the corresponding values given in Table 3A. The correlation between A and S is very small.

*Derived Unit-Hydro graph Parameters.* The derived unit-hydrograph parameters at each of the 11 gaging stations are given in Table 3B. The step-wise multiple correlation analyses yielded the following results:

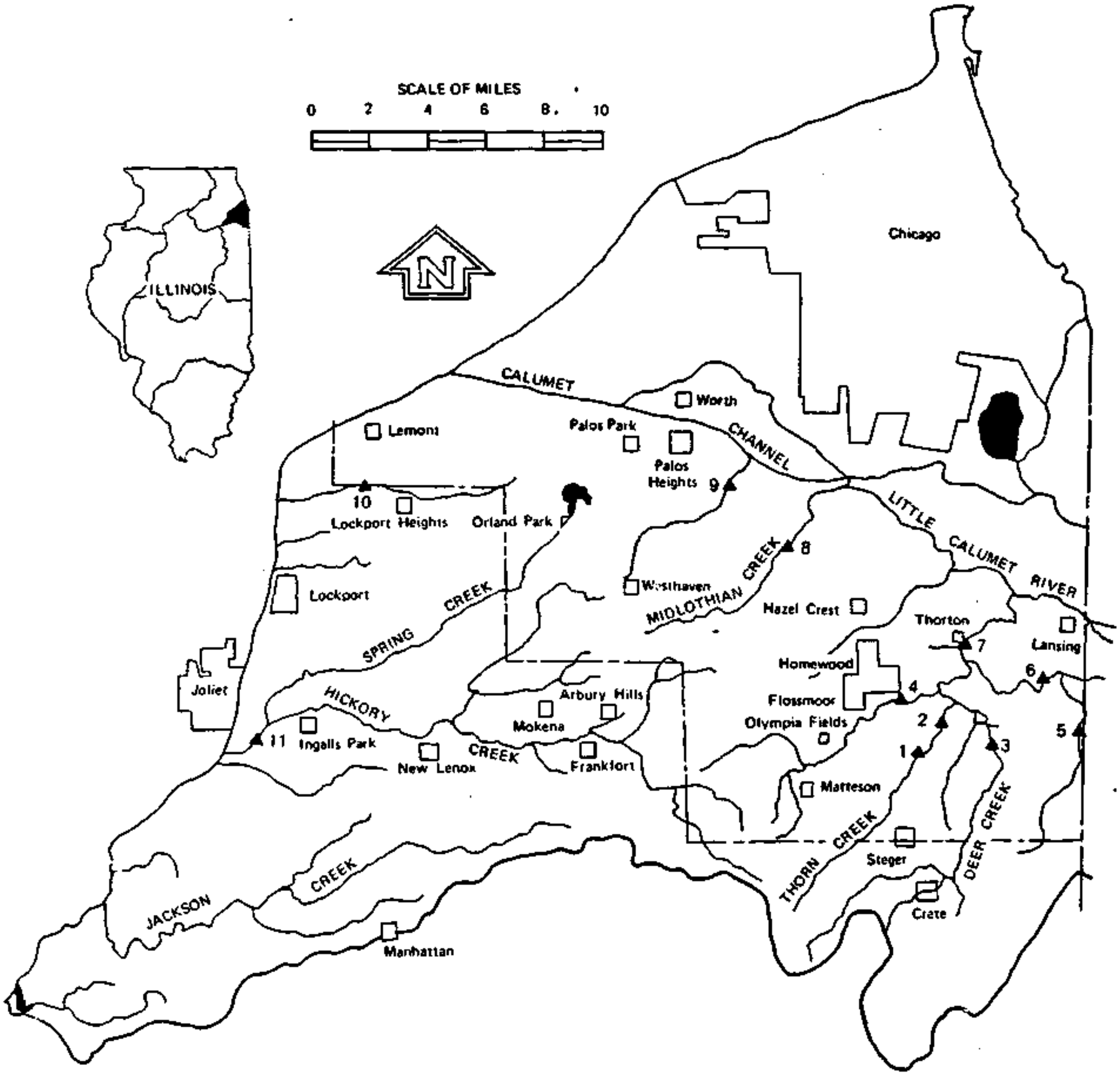



Figure 6. Study basins in region 3

$$\log t_r = 0.123 + 0.315 \log A \quad (3a)$$
$$(S_e = 0.050;\ r = 0.921)$$

$$\log t_r = -0.060 + 0.195 \log A + 0.331 \log L \quad (3b)$$
$$(S_e = 0.044;\ R = 0.945)$$

$$\log t_r = -0.003 + 0.206 \log A + 0.311 \log L - 0.054 \log S \quad (3c)$$
$$(S_e = 0.046;\ R = 0.949)$$

$$\log a = 0.614 + 0.655 \log A \quad (4a)$$
$$(S_e = 0.066;\ r = 0.965)$$

$$\log a = 0.444 + 0.642 \log A + 0.200 \log S \quad (4b)$$
$$(S_e = 0.054;\ R = 0.979)$$

$$\log a = 0.291 + 0.549 \log A + 0.254 \log L + 0.214 \log S \quad (4c)$$
$$(S_e = 0.053;\ R = 0.983)$$

Equations 3b and 4c have been used for computing the fitted $t_r$ and a, i.e., $t_r$' and a' values.

*Modified Unit-Hydrograph Parameters.* With the fitted values of $t_r$ and a, the remaining 9 unit-hydrograph parameters are modified for any difference between the derived and fitted values of the two parameters. The values of $t_r$' and a' and 9 modified parameters are given in Table 3C. The significant regression equations obtained with the step-wise multiple correlation analyses applied to the unit-hydrograph parameter as a dependent variable and the basin factors as the independent variables are as follows (the $S_e$ and R refer to the estimate of standard error and the multiple correlation coefficient from the regression between log-transformed variables, respectively):

$$tr' = 0.872\ A^{0.195}\ L^{0.331} \quad (5)$$

$$a' = 1.957\ A^{0.549}\ L^{0.254}\ S^{0.214} \quad (6)$$

$$t_p = 10.58\ A^{0.452}\ L^{-0.418}\ S^{-0.186} \quad (7)$$
$$(S_e = 0.034;\ R = 0.968)$$

$$U_p = 35.73\ A^{0.844}\ S^{0.273} \qquad (8)$$
$$(S_e = 0.078;\ R = 0.975)$$

$$t_{.75} = 8.712\ A^{0.560}\ L^{-0.603}\ S^{-0.210} \qquad (9)$$
$$(S_e = 0.034;\ R = 0.977)$$

$$d_{.75} = 5.452\ A^{0.149}\ S^{-0.078} \qquad (10)$$
$$(S_e = 0.066;\ R = 0.672)$$

$$t_{.50} = 4.168\ A^{0.548}\ L^{-0.444}\ S^{-0.138} \qquad (11)$$
$$(S_e = 0.052;\ R = 0.954)$$

$$d_{.50} = 13.93\ A^{0.131}\ S^{-0.232} \qquad (12)$$
$$(S_e = 0.070;\ R = 0.702)$$

$$t_{.25} = 1.074\ A^{0.404} \qquad (13)$$
$$(S_e = 0.061;\ r = 0.926)$$

$$d_{.25} = 51.15\ A^{0.295}\ L^{-0.405}\ S^{-0.351} \qquad (14)$$
$$(S_e = 0.080;\ R = 0.788)$$

$$t_b = 48.71\ A^{0.121}\ L^{0.125}\ S^{-0.211} \qquad (15)$$
$$(S_e = 0.070;\ R = 0.768)$$

*Fitted Unit-Hydrograph Parameters.* These parameters, obtained from equations 5 through 15, are given in Table 3D.

The 11 basins are summarized below in terms of the derived and fitted values of the unit-hydrograph peak from Tables 3C and 3D, respectively

| | | |
|---|---|---|
| fitted $U_p$ within ± 10% of derived | $U_p$ | 3 basins |
| fitted $U_p$ within ± 25% of derived | $U_p$ | 10 basins |
| remaining 1 basin | number | fitted/derived $U_p$ |
| | 7 | 1.254 |

TABLE 3. Unit-Hydrograph Parameters for Region 3

A. Basin Factors

| No. | Stream and Gaging Station | USGS No. | Area | Length | Slope |
|---|---|---|---|---|---|
| 1 | Thorn Creek near Chicago Heights | 05536210 | 17.20 | 9.62 | 17.51 |
| 2 | Thorn Creek at Glenwood | 05536215 | 24.70 | 10.47 | 15.68 |
| 3 | Deer Creek near Chicago Heights | 05536235 | 23.10 | 14.93 | 9.72 |
| 4 | Butterfield Creek at Flossmoor | 05536255 | 23.50 | 13.86 | 6.34 |
| 5 | Lansing Ditch near Lansing | 05536265 | 8.84 | 7.05 | 8.71 |
| 6 | North Creek near Lansing | 05536270 | 16.80 | 9.68 | 6.34 |
| 7 | Thorn Creek at Thornton | 05536275 | 104.00 | 15.42 | 10.82 |
| 8 | Midlothian Creek at Oak Forest | 05536340 | 12.60 | 8.95 | 3.27 |
| 9 | Tinley Creek near Palos Park | 05536500 | 11.20 | 9.56 | 11.46 |
| 10 | Long Run near Lemont | 05537500 | 20.90 | 8.17 | 7.81 |
| 11 | Hickory Creek at Joliet | 05539000 | 107.00 | 23.13 | 7.55 |

B. Derived Unit-Hydrograph Parameters

| No. | $t_r$ | $t_p$ | $U_p$ | $t_{.75}$ | $d_{.75}$ | $t_{.50}$ | $d_{.50}$ | $t_{.25}$ | $d_{.25}$ | $t_b$ | a |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3.00 | 8.50 | 1040 | 6.40 | 5.25 | 5.10 | 9.10 | 3.50 | 15.25 | 44.00 | 30 |
| 2 | 3.00 | 10.00 | 1000 | 6.70 | 8,10 | 5.60 | 12.00 | 4.00 | 20.70 | 57.00 | 40 |
| 3 | 4.00 | 10.00 | 800 | 6.50 | 8.80 | 5.50 | 13.20 | 3.50 | 23.80 | 72.00 | 35 |
| 4 | 4.00 | 9.00 | 900 | 6.40 | 7.30 | 5.40 | 12.90 | 3.80 | 23.90 | 59.00 | 30 |
| 5 | 3.00 | 9.00 | 350 | 5.40 | 7.40 | 3.60 | 13.30 | 2.20 | 23.70 | 55.00 | 15 |
| 6 | 3.00 | 11.00 | 600 | 7.60 | 7.90 | 5.70 | 14.50 | 3.30 | 26.30 | 61.00 | 20 |
| 7 | 6.00 | 18.00 | 2700 | 13.80 | 10.00 | 10.90 | 19.00 | 6.60 | 35.60 | 90.00 | 80 |
| 8 | 3.00 | 11.00 | 400 | 8.00 | 7.00 | 5.60 | 15.40 | 3.00 | 29.80 | 76.00 | 20 |
| 9 | 3.00 | 7.50 | 600 | 5.20 | 5.90 | 4.20 | 9.70 | 3.20 | 15.00 | 53.50 | 25 |
| 10 | 3.00 | 11.00 | 1000 | 8.80 | 6.20 | 7.50 | 10.40 | 4.60 | 21.10 | 48.00 | 30 |
| 11 | 6.00 | 16.50 | 4000 | 11.70 | 8.50 | 9.80 | 13.20 | 7.15 | 22.50 | 72.00 | 90 |

C. Modified Unit-Hydrograph Parameters Using Fitted $t_r$ and a

| No. | $t_r'$ | $t_p$ | $U_p$ | $t_{.75}$ | $d_{.75}$ | $t_{.50}$ | $d_{.50}$ | $t_{.25}$ | $d_{.25}$ | $t_b$ | a' |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3.21 | 8.61 | 1033 | 6.51 | 5.36 | 5.21 | 9.26 | 3.61 | 15.46 | 44.21 | 31 |
| 2 | 3.54 | 10.27 | 979 | 6.97 | 8.37 | 5.87 | 12.41 | 4.27 | 21.24 | 57.54 | 37 |
| 3 | 3.93 | 9.97 | 802 | 6.47 | 8.77 | 5.47 | 13.15 | 3.47 | 23.73 | 71.93 | 35 |
| 4 | 3.85 | 8.93 | 904 | 6.33 | 7.23 | 5.33 | 12.79 | 3.73 | 23.75 | 58.85 | 32 |
| 5 | 2.54 | 8.77 | 357 | 5.17 | 7.17 | 3.37 | 12.96 | 1.97 | 23.24 | 54.54 | 17 |

C. Modified Unit-Hydrograph Parameters Using Fitted $t_r$ and a (cont.)

| No. | $t_r'$ | $t_p$ | $U_p$ | $t_{.75}$ | $d_{.75}$ | $t_{.50}$ | $d_{.50}$ | $t_{.25}$ | $d_{.25}$ | $t_b$ | $a'$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 3.20 | 11.10 | 595 | 7.70 | 8.00 | 5.80 | 14.65 | 3.40 | 26.50 | 61.20 | 24 |
| 7 | 5.33 | 17.66 | 2755 | 13.46 | 9.66 | 10.56 | 18.50 | 6.26 | 34.93 | 89.33 | 83 |
| 8 | 2.95 | 10.98 | 400 | 7.98 | 6.98 | 5.58 | 15.36 | 2.98 | 29.75 | 75.95 | 18 |
| 9 | 2.95 | 7.47 | 601 | 5.17 | 5.87 | 4.17 | 9.66 | 3.17 | 14.95 | 53.45 | 22 |
| 10 | 3.16 | 11.08 | 995 | 8.88 | 6.28 | 7.58 | 10.52 | 4.68 | 21.26 | 48.16 | 27 |
| 11 | 6.13 | 16.56 | 3988 | 11.76 | 8.56' | 9.86 | 13.30 | 7.21 | 22.63 | 72.13 | 87 |

D. Fitted Unit-Hydrograph Parameters

| No. | $t_r$ | $t_p$ | $U_p$ | $t_{.75}$ | $d_{.75}$ | $t_{.50}$ | $d_{.50}$ | $t_{.25}$ | $d_{.25}$ | $t_b$ | a |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3.21 | 8.71 | 862 | 6.00 | 6.67 | 4.88 | 10.39 | 3.39 | 17.34 | 49.96 | 31 |
| 2 | 3.54 | 10.10 | 1135 | 7.15 | 7.10 | 5.82 | 11.18 | 3.93 | 19.38 | 54.00 | 37 |
| 3 | 3.93 | 9.23 | 941 | 6.14 | 7.29 | 5.12 | 12.39 | 3.82 | 19.47 | 61.95 | 35 |
| 4 | 3.85 | 10.39 | 850 | 7.10 | 7.56 | 5.66 | 13.71 | 3.85 | 23.42 | 67.30 | 32 |
| 5 | 2.54 | 8.36 | 406 | 5.77 | 6.37 | 4.28 | 11.21 | 2.59 | 20.64 | 51.35 | 17 |
| 6 | 3.20 | 10.38 | 640 | 7.30 | 7.19 | 5.53 | 13.12 | 3.36 | 24.53 | 61.77 | 24 |
| 7 | 5.33 | 17.61 | 3454 | 13.68 | 9.05 | 11.33 | 14.71 | 7.02 | 28.85 | 72.99 | 83 |
| 8 | 2.95 | 10.65 | 419 | 7.49 | 7.25 | 5.36 | 14.74 | 2.99 | 29.35 | 67.92 | 18 |
| 9 | 2.95 | 7.78 | 534 | 5.18 | 6.46 | 4.10 | 10.84 | 2.85 | 17.77 | 51.82 | 22 |
| 10 | 3.16 | 11.83 | 815 | 8.75 | 7.31 | 6.53 | 12.86 | 3.67 | 26.05 | 59.42 | 27 |
| 11 | 6.13 | 16.10 | 3206 | 11.74 | 9.35 | 10.11 | 16.05 | 7.10 | 28.01 | 83.14 | 87 |

## REGION 4

The rivers, streams and tributaries included in this region are shown in figure 7. together with the location of the 12 gaging stations used for deriving the unit-hydrograph parameters. These gaging stations; their USGS number; drainage area, A, above the gaging station; main-channel length, L; and main-channel slope, S; are given in Table 4A.

*Basin Factors.* Simple correlation with log A as an independent variable and log L or log S as a dependent variable yields the following:

$$\log L = 0.371 + 0.519 \log A \qquad (1)$$
$$(S_e = 0.142;\ r = 0.969;\ \Sigma\Delta^2 = 0.203)$$

$$\log S = 1.598 - 0.400 \log A \qquad (2)$$
$$(S_e = 0.259;\ r = 0.858;\ \Sigma\Delta^2 = 0.673)$$

About one-half of $\sum\Delta^2$ ($\Delta^2$ is the square of the difference between the logarithms of given and fitted values of the dependent variable) for the relation expressed by equation 1 comes from basins 1, 2, 3 and 4. More than one-half of $\sum\Delta^2$ for the relation given by equation 2 comes from basins 4, 7 and 8. No basins yield values of L from equation 1 that exceed by more than 50 percent the corresponding values given in Table 4A. However, the values of S fitted according to equation 2 are more than 50 percent lower for basins 6, 7 and 8, and more than 50 percent higher for basins 2, 4 and 12 than the corresponding values given in Table 4A. This indicates that L and A are much more highly correlated than S and A.

*Derived Unit-Hydrograph Parameters.* The derived unit-hydrograph parameters at each of the 12 gaging stations are given in Table 4B. The step-wise multiple correlation analyses yielded the following results:

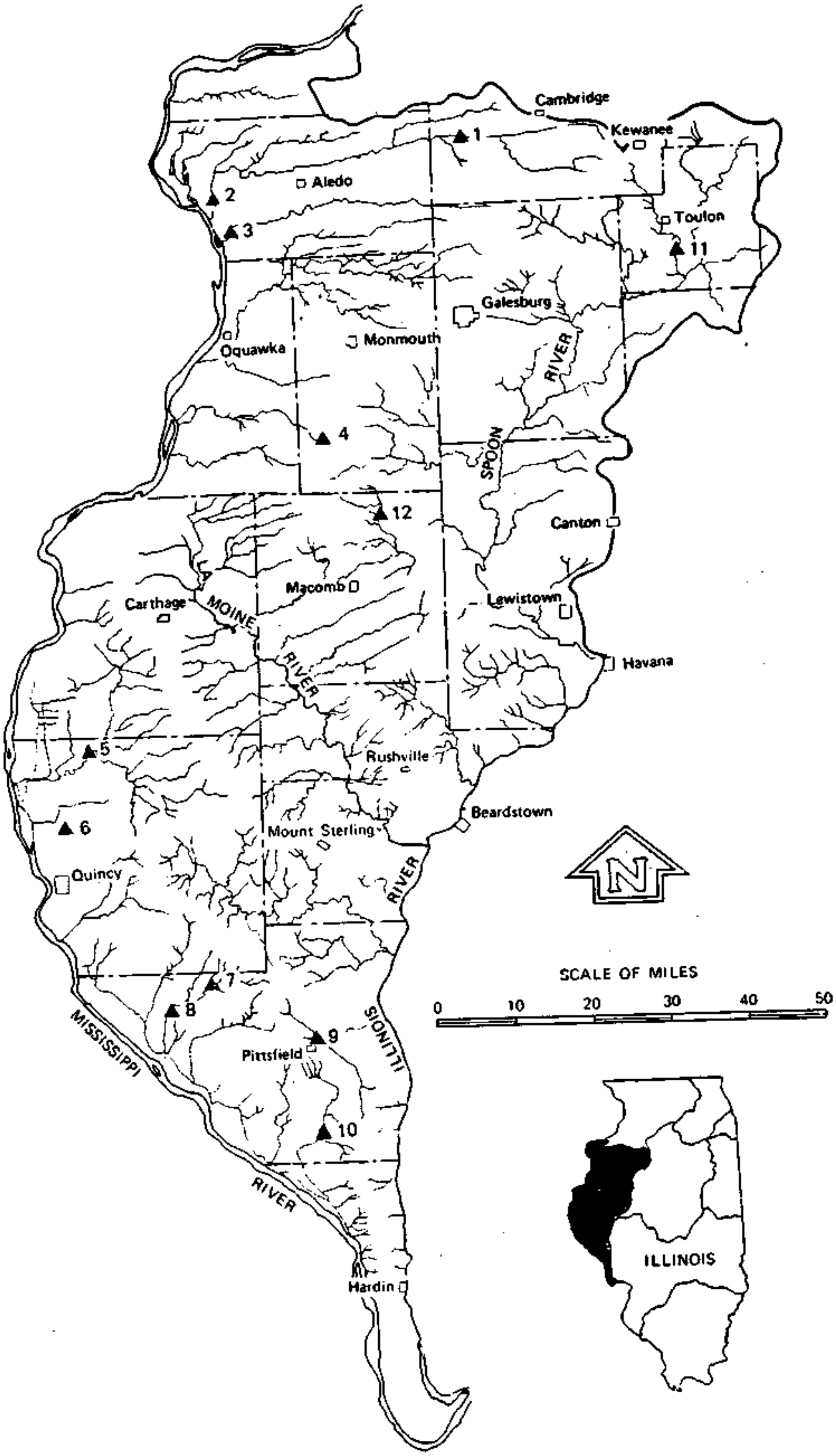



Figure 7. Study basins in region 4

$$\log t_r = -0.911 + 0.968 \log L \qquad (3a)$$
$$(S_e = 0.049;\ r = 0.996)$$

$$\log t_r = -0.825 + 0.151 \log A + 0.695 \log L \qquad (3b)$$
$$(S_e = 0.030;\ R = 0.999)$$

$$\log t_r = -0.801 + 0.154 \log A + 0.680 \log L - 0.012 \log S \qquad (3c)$$
$$(S_e = 0.031;\ R = 0.999)$$

$$\log a = 1.706 + 0.749 \log S \qquad (4a)$$
$$(S_e = 0.138;\ r = 0.939)$$

$$\log a = 1.139 + 0.257 \log L + 1.019 \log S \qquad (4b)$$
$$(S_e = 0.131;\ R = 0.951)$$

$$\log a = 1.167 + 0.022 \log A + 0.211 \log L + 1.011 \log S \qquad (4c)$$
$$(S_e = 0.138;\ R = 0.951)$$

Equations 3b and 4b have been used for computing the fitted $t_r$ and a, i.e., $t_r'$ and a' values.

*Modified Unit-Hydrograph Parameters.* With the fitted values of $t_r$ and a, the remaining 9 unit-hydrograph parameters are modified for any difference between the derived and fitted values of the two parameters. The values of $t_r'$ and a' and 9 modified parameters are given in Table 4C. The significant regression equations obtained with the step-wise multiple correlation analyses applied to the unit-hydrograph parameter as a dependent variable and the basin factors as the independent variables are as follows (the $S_e$ and R refer to the estimate of standard error and the multiple correlation coefficient from the regression between log-transformed variables, respectively):

$$t_r' = 0.150\ A^{0.151}\ L^{0.695} \qquad (5)$$

$$a' = 13.76\ L^{0.257}\ S^{1.019} \qquad (6)$$

$$t_p = 5.275\ A^{0.336}\ S^{-0.514} \qquad (7)$$
$$(S_e = 0.045;\ R = 0.998)$$

$$U_p = 73.91\ A^{0.692}\ S^{0.631} \tag{8}$$
$$(S_e = 0.052;\ R = 0.995)$$

$$t_{.75} = 3.787\ A^{0.333}\ S^{-0.506} \tag{9}$$
$$(S_e = 0.040;\ R = 0.998)$$

$$d_{.75} = 3.342\ A^{0.347}\ S^{-0.547} \tag{10}$$
$$(S_e = 0.049;\ R = 0.997)$$

$$t_{.50} = 2.751\ A^{0.343}\ S^{-0.487} \tag{11}$$
$$(S_e = 0.040;\ R = 0.998)$$

$$d_{.50} = 5.765\ A^{0.331}\ S^{-0.558} \tag{12}$$
$$(S_e = 0.043;\ R = 0.998)$$

$$t_{.25} = 1.852\ A^{0.356}\ S^{-0.477} \tag{13}$$
$$(S_e = 0.050;\ R = 0.997)$$

$$d_{.25} = 11.23\ A^{0.313}\ S^{-0.622} \tag{14}$$
$$(S_e = 0.053;\ R = 0.997)$$

$$t_b = 19.68\ A^{0.358}\ S^{-0.562} \tag{15}$$
$$(S_e = 0.104;\ R = 0.988)$$

*Fitted Unit-Hydrograph Parameters.* These parameters, obtained from equations 5 through 15, are given in Table 4D. All the equations, except $t_r'$ and a', use A and S as independent variables.

The 12 basins are summarized below in terms of the derived and fitted values of the unit-hydrograph peak from Table 4C and 4D, respectively.

fitted $U_p$ within ± 10% of derived $U_p$ 7 basins

fitted $U_p$ within ± 25% of derived $U_p$ 12 basins

TABLE 4. Unit Hydrograph Parameters for Region 4

A. Basin Factors

| No. | Stream and Gaging Station | USGS No. | Area | Length | Slope |
|---|---|---|---|---|---|
| 1 | Edwards River near Orion | 05466000 | 155.00 | 22.91 | 5.07 |
| 2 | Edwards River near New Boston | 05466500 | 445.00 | 78.48 | 1.69 |
| 3 | Pope Creek near Keithsburg | 05467000 | 183.00 | 57.02 | 3.59 |
| 4 | Ellison Creek Trib. near Roseville | 05469750 | .26 | 1.67 | 28.78 |
| 5 | Bear Creek near Marcelline | 05495500 | 349.00 | 36.18 | 3.70 |
| 6 | Homan Creek Tributary near Quincy | 05496900 | .50 | 1.29 | 105.60 |
| 7 | Hadley Creek near Barry | 05502020 | 40.90 | 11.69 | 19.75 |
| 8 | Hadley Creek near Kinderhook | 05502040 | 72.70 | 17.72 | 15.00 |
| 9 | Bay Creek at Pittsfield | 05512500 | 39.40 | 12.20 | 11.25 |
| 10 | Bay Creek at Nebo | 05513000 | 161.00 | 39.78 | 7.02 |
| 11 | Indian Creek near Wyoming | 05568800 | 62.70 | 26.67 | 6.44 |
| 12 | Drowning Fork at Bushnell | 05584400 | 26.30 | 12.57 | 5.76 |

B. Derived Unit-Hydrograph Parameters

| No. | $t_r$ | $t_p$ | $U_p$ | $t_{.75}$ | $d_{.75}$ | $t_{.50}$ | $d_{.50}$ | $t_{.25}$ | $d_{.25}$ | $t_b$ | a |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3.00 | 11.00 | 7300 | 8.10 | 7.70 | 6.90 | 12.35 | 5.60 | 19.00 | 36.00 | 300 |
| 2 | 8.00 | 29.00 | 8040 | 21.70 | 19.30 | 17.70 | 31.40 | 13.50 | 50.50 | 108.00 | 80 |
| 3 | 6.00 | 18.00 | 5400 | 13.00 | 10.00 | 7.80 | 16.70 | 5.60 | 29.20 | 79.00 | 120 |
| 4 | .17 | .54 | 280 | .41 | .29 | .32 | .49 | .23 | .80 | 1.50 | 600 |
| 5 | 4.00 | 21.00 | 9800 | 14.00 | 13.70 | 11.00 | 18.50 | 7.80 | 27.70 | 76.00 | 100 |
| 6 | .17 | .42 | 800 | .32 | .22 | .24 | .38 | .17 | .56 | 1.17 | 1500 |
| 7 | 1.50 | 4.00 | 6400 | 2.90 | 2.25 | 2.30 | 3.50 | 1.45 | 5.30 | 16.00 | 500 |
| 8 | 2.00 | 5.00 | 8800 | 3.60 | 3.10 | 2.90 | 4.90 | 2.20 | 7.10 | 18.00 | 500 |
| 9 | 1.50 | 5.00 | 4500 | 3.50 | 3.50 | 2.80 | 5.40 | 2.40 | 7.10 | 18.50 | 300 |
| 10 | 4.00 | 10.00 | 8700 | 7.75 | 5.70 | 6.70 | 9.25 | 5.25 | 18.40 | 31.50 | 300 |
| 11 | 2.50 | 9.00 | 3600 | 6.50 | 5.80 | 5.20 | 9.00 | 3.10 | 15.10 | 44.00 | 200 |
| 12 | 1.50 | 7.00 | 1800 | 4.75 | 4.50 | 3.75 | 7.20 | 2.50 | 11.70 | 31.00 | 100 |

C. Modified Unit-Hydrograph Parameters Using Fitted $t_r$ and a

| No. | $t_r'$ | $t_p$ | $U_p$ | $t_{.75}$ | $d_{.75}$ | $t_{.50}$ | $d_{.50}$ | $t_{.25}$ | $d_{.25}$ | $t_b$ | a' |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.82 | 10.91 | 7328 | 8.01 | 7.61 | 6.81 | 12.22 | 5.51 | 18.82 | 35.82 | 161 |
| 2 | 7.79 | 28.89 | 8055 | 21.59 | 19.19 | 17.59 | 31.24 | 13.39 | 50.29 | 107.79 | 72 |
| 3 | 5.46 | 17.73 | 5477 | 12.73 | 9.73 | 7.53 | 16.29 | 5.33 | 28.66 | 78.46 | 143 |
| 4 | .17 | .54 | 276 | .41 | .30 | .33 | .49 | .23 | .81 | 1.51 | 481 |
| 5 | 4.38 | 21.19 | 9749 | 14.19 | 13.89 | 11.19 | 18.79 | 7.99 | 28.08 | 76.38 | 131 |
| 6 | .16 | .41 | 810 | .31 | .22 | .23 | .38 | .16 | .55 | 1.16 | 1692 |
| 7 | 1.45 | 3.97 | 6428 | 2.87 | 2.22 | 2.27 | 3.46 | 1.42 | 5.25 | 15.95 | 541 |
| 8 | 2.11 | 5.05 | 8751 | 3.65 | 3.15 | 2.95 | 4.98 | 2.25 | 7.21 | 18.11 | 455 |
| 9 | 1.48 | 4.99 | 4505 | 3.49 | 3.49 | 2.79 | 5.39 | 2.39 | 7.08 | 18.48 | 308 |
| 10 | 4.17 | 10.08 | 8656 | 7.83 | 5.78 | 6.78 | 9.38 | 5.33 | 18.57 | 31.67 | 258 |
| 11 | 2.74 | 9.12 | 3549 | 6.62 | 5.92 | 5.32 | 9.18 | 3.22 | 15.34 | 44.24 | 214 |
| 12 | 1.42 | 6.96 | 1811 | 4.71 | 4.46 | 3.71 | 7.14 | 2.46 | 11.62 | 30.92 | 157 |

D. Fitted Unit-Hydrograph Parameters

| No. | $t_r$ | $t_p$ | $U_p$ | $t_{.75}$ | $d_{.75}$ | $t_{.50}$ | $d_{.50}$ | $t_{.25}$ | $d_{.25}$ | $t_b$ | a |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.82 | 12.46 | 6763 | 8.96 | 7.90 | 7.03 | 12.35 | 5.14 | 19.77 | 48.09 | 161 |
| 2 | 7.79 | 31.25 | 7014 | 22.19 | 20.78 | 17.22 | 32.32 | 12.62 | 54.47 | 130.06 | 72 |
| 3 | 5.46 | 15.74 | 6101 | 11.27 | 10.11 | 8.80 | 15.82 | 6.42 | 25.82 | 61.96 | 143 |
| 4 | .17 | .60 | 242 | .44 | .33 | .34 | .57 | .23 | .91 | 1.84 | 481 |
| 5 | 4.38 | 19.25 | 9723 | 13.77 | 12.44 | 10.82 | 19.26 | 7.97 | 31.00 | 76.76 | 131 |
| 6 | .16 | .38 | 867 | .29 | .21 | .22 | .34 | .16 | .50 | 1.12 | 1692 |
| 7 | 1.45 | 3.96 | 6346 | 2.89 | 2.37 | 2.30 | 3.72 | 1.67 | 5.59 | 13.90 | 541 |
| 8 | 2.11 | 5.53 | 7943 | 4.02 | 3.36 | 3.20 | 5.25 | 2.34 | 7.95 | 19.94 | 455 |
| 9 | 1.48 | 5.22 | 4334 | 3.79 | 3.18 | 2.98 | 5.03 | 2.16 | 7.85 | 18.82 | 308 |
| 10 | 4.17 | 10.68 | 8527 | 7.70 | 6.70 | 6.08 | 10.43 | 4.46 | 16.34 | 40.60 | 258 |
| 11 | 2.74 | 8.13 | 4204 | 5.87 | 5.07 | 4.59 | 8.01 | 3.32 | 12.84 | 30.41 | 214 |
| 12 | 1.42 | 6.43 | 2147 | 4.65 | 3.98 | 3.60 | 6.40 | 2.57 | 10.49 | 23.72 | 157 |

## REGION 5

The rivers, streams and tributaries included in this region are shown in figure 8, together with the location of the 26 gaging stations used for deriving the unit-hydrograph parameters. These gaging stations; their USGS number; drainage area, A, above the gaging station; main-channel length, L; and main-channel slope, S; are given in Table 5A.

*Basin Factors.* Simple correlation with log A as an independent variable and log L or log S as a dependent variable yields the following:

$$\log L = 0.182 + 0.594 \log A \tag{1}$$
$$(S_e = 0.132;\ r = 0.975;\ \Sigma\Delta^2 = 0.417)$$

$$\log S = 1.492 - 0.304 \log A \tag{2}$$
$$(S_e = 0.224;\ r = 0.796;\ \Sigma\Delta^2 = 1.204)$$

About one-half of $\sum\Delta^2$ ($\Delta^2$ is the square of the difference between the logarithms of given and fitted values of the independent variable) for the relation expressed by equation 1 comes from basins 1, 13, 14 and 18. More than one-half of $\sum\Delta^2$ for the relation given by equation 2 comes from basins 7, 9, 10 and 17. Only basins 1 and 18 yield values of L from equation 1 that exceed by more than 50 percent the corresponding values given in Table 5A. Similarly, the values of S fitted according to equation 2 are more than 50 percent lower for basins 7, 9 and 10 and more than 50 percent higher for basins 13, 14, 16, 17, 18 and 19 than the corresponding values given in. Table 5A. This indicates that L and A are much more highly correlated than S and A.

*Derived Unit-Hydrograph Parameters.* The derived unit-hydrograph parameters at each of the 26 gaging stations are given in Table 5B. The step-wise multiple correlation analyses yielded the following results:

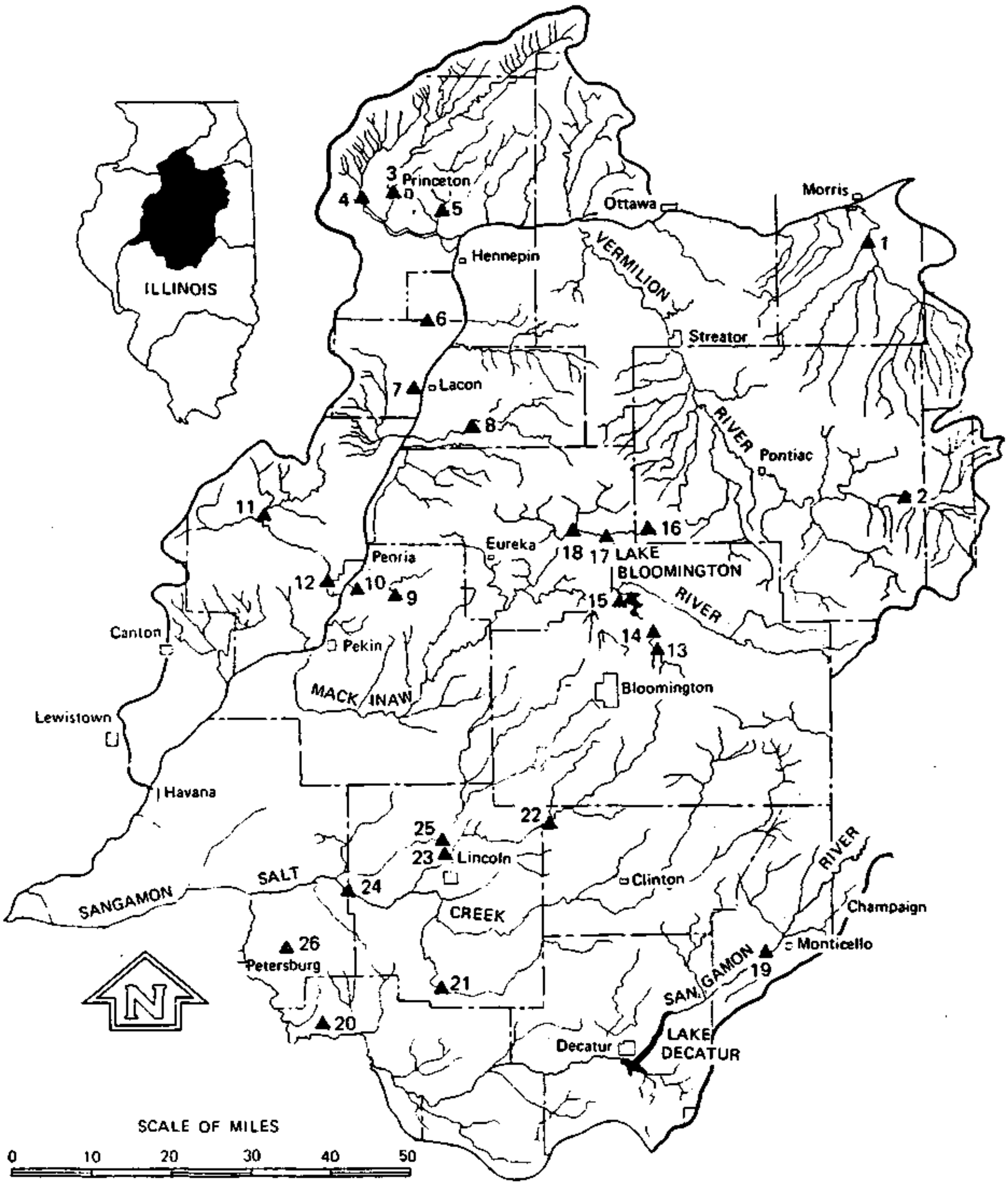



Figure 8. Study basins in region 5

$$\log t_r = -0.473 + 0.513 \log A \quad (3a)$$
$$(S_e = 0.063;\ r = 0.992)$$

$$\log t_r = -0.324 + 0.482 \log A - 0.100 \log S \quad (3b)$$
$$(S_e = 0.060;\ R = 0.993)$$

$$\log t_r = -0.334 + 0.437 \log A + 0.075 \log L - 0.102 \log S \quad (3c)$$
$$(S_e = 0.060;\ R = 0.993)$$

$$\log a = 1.521 + 0.617 \log S \quad (4a)$$
$$(S_e = 0.159;\ r = 0.821)$$

$$\log a = 0.577 + 0.256 \log A + 1.151 \log S \quad (4b)$$
$$(S_e = 0.053;\ R = 0.983)$$

$$\log a = 0.566 + 0.206 \log A + 0.083 \log L + 1.149 \log S \quad (4c)$$
$$(S_e = 0.053;\ R = 0.983)$$

Equations 3b and 4b have been used for computing the fitted $t_r$ and a, i.e., $t_r$' and a' values.

*Modified Unit-Hydrograph Parmeters.* With the fitted values of $t_r$ and a, the remaining 9 unit-hydrograph parameters are modified for any difference between the derived and fitted values of the two parameters. The values of $t_r$' and a' and 9 modified parameters are given in Table 5C. The significant regression equations obtained with the step-wise multiple correlation analyses applied to the unit-hydrograph parameter as a dependent variable and the basin factors as the independent variables are as follows (the $S_e$ and R refer to the estimate of standard error and the multiple correlation coefficient from the regression between log-trans formed variables, respectively):

$$t_r' = 0.474\ A^{0.482}\ S^{-0.100} \quad (5)$$

$$a' = 3.777\ A^{0.256}\ S^{1.151} \quad (6)$$

$$t_p = 4.539\ A^{0.388}\ S^{-0.453} \quad (7)$$
$$(S_e = 0.054;\ R = 0.995)$$

$$U_p = 43.76\ A^{0.701}\ S^{0.709} \tag{8}$$
$$(S_e = 0.080;\ R = 0.988)$$

$$t_{.75} = 3.600\ A^{0.374}\ S^{-0.469} \tag{9}$$
$$(S_e = 0.065;\ R = 0.992)$$

$$d_{.75} = 4.561\ A^{0.360}\ S^{-0.593} \tag{10}$$
$$(S_e = 0.076;\ R = 0.991)$$

$$t_{.50} = 3.005\ A^{0.374}\ S^{-0.481} \tag{11}$$
$$(S_e = 0.062;\ R = 0.993)$$

$$d_{.50} = 9.184\ A^{0.334}\ S^{-0.645} \tag{12}$$
$$(S_e = 0.083;\ R = 0.989)$$

$$t_{.25} = 2.223\ A^{0.369}\ S^{-0.493} \tag{13}$$
$$(S_e = 0.065;\ R = 0.992)$$

$$d_{.25} = 23.40\ A^{0.289}\ S^{-0.763} \tag{14}$$
$$(S_e = 0.088;\ R = 0.987)$$

$$t_b = 55.73\ A^{0.281}\ S^{-0.709} \tag{15}$$
$$(S_e = 0.070;\ R = 0.991)$$

*Fitted Unit-Hydrograph Parameters.* These parameters, obtained from equations 5 through 15, are given in Table 5D. All the equations 5-15 use A and S as independent variables.

The 26 basins are summarized below in terms of the derived and fitted values of the unit-hydrograph peak from Table 5C and 5D, respectively.

fitted $U_p$ within ± 10% of derived $U_p$ — 13 basins

fitted $U_p$ within ± 25% of derived $U_p$ — 22 basins

remaining 4 basins:

| number | fitted/derived $U_p$ |
|---|---|
| 2 | 1.309 |
| 11 | 0.676 |
| 20 | 1.265 |
| 21 | 1.532 |

TABLE 5. Unit Hydrograph-Parameters for Region 5

A. Basin Factors

| No. | Stream and Gaging Station | USGS No. | Area | Length | Slope |
|---|---|---|---|---|---|
| 1 | Mazon River near Coal City | 05542000 | 455.00 | 36.27 | 4.33 |
| 2 | N. Fork Vermilion River near Charlotte | 05554000 | 186.00 | 23.00 | 5.39 |
| 3 | Big Bureau Creek at Princeton | 05556500 | 196.00 | 54.59 | 6.07 |
| 4 | West Bureau Creek at Wyanet | 05557000 | 86.70 | 22.54 | 9.03 |
| 5 | East Bureau Creek near Bureau | 05557500 | 99.00 | 23.50 | 12.72 |
| 6 | Crow Creek (west) near Henry | 05558500 | 56.20 | .27.49 | 10.24 |
| 7 | Gimlet Creek at Sparland | 05559000 | 5.66 | 4.81 | 53.86 |
| 8 | Crow Creek near Washburn | 05559500 | 115.00 | 27.68 | 6.07 |
| 9 | Ackerman Creek at Farmdale | 05561000 | 11.20 | 6.72 | 39.86 |
| 10 | Farm Creek at East Peoria | 05562000 | 61.20 | 18.60 | 18.90 |
| 11 | Kickapoo Creek near Kickapoo | 05563000 | 119.00 | 22.18 | 10.93 |
| 12 | Kickapoo Creek at Peoria | 05563500 | 297.00 | 39.36 | 7.50 |
| 13 | Money Creek near Towanda | 05564400 | 49.00 | 25.78 | 5.25 |
| 14 | Money Creek above Lake Bloomington | 05564500 | 53.10 | 29.20 | 4.91 |
| 15 | Hickory Creek above Lake Bloomington | 05565000 | 9.81 | 6.74 | 11.88 |
| 16 | East Branch Panther Creek near Gridley | 05566000 | 6.30 | 3.11 | 11.14 |
| 17 | East Branch Panther Creek at E1 Paso | 05566500 | 30.50 | 8.47 | 4.54 |
| 18 | Panther Creek near E1 Paso | 05567000 | 93.90 | 13.59 | 4,22 |
| 19 | Wildcat Creek Tributary near Monticello | 05572100 | .10 | .37 | 34.11 |
| 20 | Sangamon River Tributary at Andrew | 05577700 | 1.50 | 1.36 | 40.13 |
| 21 | Lake Fork near Cornland | 05579500 | 214.00 | 37.00 | 4.65 |
| 22 | Kickapoo Creek at Waynesville | 05580000 | 227.00 | 36.08 | 6.23 |
| 23 | Kickapoo Creek at Lincoln | 05580500 | 306.00 | 54.48 | 5.12 |
| 24 | Salt Creek Tributary at Middletown | 05580700 | .90 | 1.55 | 48.94 |
| 25 | Sugar Creek near Hartsburg | 05581500 | 333.00 | 42.77 | 5.76 |
| 26 | Cabiness Creek Tributary nr. Petersburg | 05582200 | .94 | 1.57 | 23.76 |

B. Derived Unit-Hydrograph Parameters

| No. | $t_r$ | $t_p$ | $U_p$ | $t_{.75}$ | $d_{.75}$ | $t_{.50}$ | $d_{.50}$ | $t_{.25}$ | $d_{.25}$ | $t_b$ | a |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 8.00 | 24.00 | 10400 | 17.30 | 14.70 | 14.00 | 24.00 | 10.00 | 38.50 | 95.00 | 100 |
| 2 | 5.00 | 15.50 | 4300 | 12.00 | 12.20 | 9.00 | 25.05 | 6.30 | 39.40 | 85.50 | 100 |
| 3 | 5.00 | 14.00 | 7000 | 7.20 | 10.30 | 6.00 | 15.00 | 4.00 | 23.50 | 69.00 | 100 |
| 4 | 3.00 | 9.00 | 5000 | 6.30 | 5.70 | 5.00 | 9.00 | 3.50 | 13.70 | 41.00 | 160 |
| 5 | 3.00 | 7.50 | 6800 | 5.50 | 4.60 | 4.50 | 7.50 | 3.60 | 11.20 | 47.00 | 250 |

B. Derived Unit-Hydrograph Parameters (continued)

| No. | $t_r$ | $t_p$ | $U_p$ | $t_{.75}$ | $d_{.75}$ | $t_{.50}$ | $d_{.50}$ | $t_{.25}$ | $d_{.25}$ | $t_b$ | a |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 3.00 | 9.00 | 3350 | 6.50 | 6.30 | 5.20 | 9.30 | 3.50 | 14.80 | 39.00 | 150 |
| 7 | 1.00 | 1.50 | 2400 | 1.00 | .90 | .80 | 1.30 | .65 | 1.85 | 5.25 | 700 |
| 8 | 4.00 | 12.50 | 5000 | 9.20 | 7.50 | 7.60 | 11.90 | 5.50 | 19.70 | 56.00 | 100 |
| 9 | 1.00 | 2.33 | 3000 | 1.73 | 1.25 | 1.30 | 2.17 | .80 | 3.28 | 7.83 | 500 |
| 10 | 2.00 | 5.00 | 7000 | 4.00 | 3.25. | 3.50 | 5.00 | 2.50 | 7.60 | 21.00 | 350 |
| 11 | 4.00 | 8.00 | 10000 | 6.30 | 4.30 | 5.75 | 6.75 | 4.51 | 10.20 | 30.50 | 200 |
| 12 | 5.00 | 14.50 | 13000 | 11.20 | 8.80 | 9.20 | 12.80 | 6.50 | 20.60 | 47.50 | 160 |
| 13 | 3.00 | 9.00 | 2200 | 6.80 | 6.80 | 5.70 | 11.30 | 4.00 | 20.60 | 48.00 | 80 |
| 14 | 3.00 | 9.00 | 2200 | 7.00 | 6.90 | 5.75 | 13.25 | 4.50 | 25.70 | 50.00 | 80 |
| 15 | 1.25 | 3.50 | 1200 | 2.60 | 2.50 | 2.15 | 4.45 | 1.75 | 7.60 | 18.50 | 120 |
| 16 | 1.00 | 3.50 | 700 | 2.50 | 2.50 | 2.00 | 4.10 | 1.20 | 7.80 | 23.50 | 80 |
| 17 | 2.00 | 8.50 | 1600 | 6.00 | 5.50 | 4.90 | 8.60 | 3.50 | 16.80 | 43.00 | 50 |
| 18 | 4.00 | 13.00 | 3200 | 9.00 | 11.30 | 7.50 | 16.60 | 6.00 | 26.00 | 68.00 | 80 |
| 19 | .08 | .33 | 130 | .28 | .19 | .23 | .36 | .17 | .57 | 2.17 | 120 |
| 20 | .42 | 1.12 | 625 | .78 | .77 | .58 | 1.30 | .37 | 2.10 | 4.80 | 250 |
| 21 | 6.00 | 24.00 | 3600 | 17.20 | 20.40 | 14.20 | 31.60 | 10.00 | 51.00 | 112.00 | 80 |
| 22 | 5.00 | 20.00 | 6000 | 14.50 | 12.40 | 11.50 | 19.70 | 8.30 | 33.20 | 76.00 | 120 |
| 23 | 6.00 | 21.00 | 7600 | 15.50 | 13.80 | 12.10 | 22.70 | 7.30 | 32.80 | 86.00 | 100 |
| 24 | .33 | .82 | 600 | .61 | .48 | .50 | .77 | .35 | 1.3 | 3.40 | 300 |
| 25 | 6.00 | 23.00 | 8200 | 16.90 | 12.30 | 13.50 | 20.30 | 8.30 | 36.50 | 83.00 | 100 |
| 26 | .33 | 1.09 | 450 | .84 | .62 | .67 | "1.02 | .49 | 2.00 | 5.58 | 150 |

C. Modified Unit-Hydrograph Parameters Using Fitted $t_r$ and a

| No. | $t_r'$ | $t_p$ | $U_p$ | $t_{.75}$ | $d_{.75}$ | $t_{.50}$ | $d_{.50}$ | $t_{.25}$ | $d_{.25}$ | $t_b$ | a' |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 7.84 | 23.92 | 10416 | 17.22 | 14.62 | 13.92 | 23.88 | 9.92 | 38.34 | 94.84 | 98 |
| 2 | 4.98 | 15.49 | 4302 | 11.99 | 12.19 | 8.99 | 25.03 | 6.29 | 39.38 | 85.48 | 100 |
| 3 | 5.05 | 14.02 | 6994 | 7.22 | 10.32 | 6.02 | 15.03 | 4.02 | 23.55 | 69.05 | 116 |
| 4 | 3.27 | 9.14 | 4959 | 6.44 | 5.84 | 5.14 | 9.20 | 3.64 | 13.97 | 41.27 | 149 |
| 5 | 3.37 | 7.69 | 6714 | 5.69 | 4.79 | 4.69 | 7.78 | 3.79 | 11.57 | 47.37 | 229 |
| 6 | 2.62 | 8.81 | 3408 | 6.31 | 6.11 | 5.01 | 9.02 | 3.31 | 14.42 | 38.62 | 154 |
| 7 | .73 | 1.37 | 2554 | .87 | .77 | .67 | 1.10 | .52 | 1.58 | 4.98 | 580 |
| 8 | 3.90 | 12.45 | 5009 | 9.15 | 7.45 | 7.55 | 11.83 | 5.45 | 19.60 | 55.90 | 102 |
| 9 | 1.05 | 2.36 | 2974 | 1.76 | 1.28 | 1.33 | 2.21 | .83 | 3.33 | 7.88 | 488 |
| 10 | 2.57 | 5.28 | 6818 | 4.28 | 3.53 | 3.78 | 5.43 | 2.78 | 8.17 | 21.57 | 319 |
| 11 | 3.74 | 7.87 | 10052 | 6.17 | 4.17 | 5.62 | 6.56 | 4.38 | 9.94 | 30.24 | 202 |
| 12 | 6.04 | 15.02 | 12828 | 11.72 | 9.32 | 9.72 | 13.58 | 7.02 | 21.64 | 48.54 | 165 |
| 13 | 2.62 | 8.81 | 2225 | 6.61 | 6.61 | 5.51 | 11.02 | 3.81 | 20.22 | 47.62 | 69 |
| 14 | 2.75 | 8.87 | 2216 | 6.87 | 6.77 | 5.62 | 13.06 | 4.37 | 25.45 | 49.75 | 65 |
| 15 | 1.11 | 3.43 | 1215 | 2.53 | 2.43 | 2.08 | 4.35 | 1.68 | 7.46 | 18.36 | 117 |

C. Modified Unit-Hydrograph Parameters Using Fitted $t_r$ and a (continued)

| No. | $t_r'$ | $t_p$ | $U_p$ | $t_{.75}$ | $d_{.75}$ | $t_{.50}$ | $d_{.50}$ | $t_{.25}$ | $d_{.25}$ | $t_b$ | a' |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 16 | .90 | 3.45 | 709 | 2.45 | 2.45 | 1.95 | 4.03 | 1.15 | 7.70 | 23.40 | 97 |
| 17 | 2.12 | 8.56 | 1593 | 6.06 | 5.56 | 4.96 | 8.69 | 3.56 | 16.92 | 43.12 | 52 |
| 18 | 3.67 | 12.83 | 3220 | 8.83 | 11.13 | 7.33 | 16.35 | 5.83 | 25.67 | 67.67 | 63 |
| 19 | .11 | .34 | 126 | .29 | .20 | .24 | .38 | .18 | .60 | 2.20 | 122 |
| 20 | .40 | 1.11 | 631 | .77 | .76 | .57 | 1.28 | .36 | 2.08 | 4.78 | 294 |
| 21 | 5.41 | 23.70 | 3652 | 16.90 | 20.10 | 13.90 | 31.16 | 9.70 | 50.41 | 111.41 | 88 |
| 22 | 5.40 | 20.20 | 5949 | 14.70 | 12.60 | 11.70 | 20.00 | 8.50 | 33.60 | 76.40 | 125 |
| 23 | 6.36 | 21.18 | 7561 | 15.68 | 13.98 | 12.28 | 22.97 | 7.48 | 33.16 | 86.36 | 107 |
| 24 | .31 | .81 | 607 | .60 | .47 | .49 | .75 | .34 | 1.31 | 3.38 | 324 |
| 25 | 6.55 | 23.28 | 8130 | 17.18 | 12.58 | 13.78 | 20.71 | 8.58 | 37.05 | 83.55 | 126 |
| 26 | .34 | 1.09 | 449 | .84 | .62 | .67 | 1.02 | .49 | 2.01 | 5.59 | 143 |

D. Fitted Unit-Hydrograph Parameters

| No. | $t_r$ | $t_p$ | $U_p$ | $t_{.75}$ | $d_{.75}$ | $t_{.50}$ | $d_{.50}$ | $t_{.25}$ | $d_{.25}$ | $t_b$ | a |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 7.84 | 25.05 | 9026 | 17.88 | 17.29 | 14.65 | 27.56 | 10.34 | 44.81 | 110.01 | 94 |
| 2 | 4.98 | 16.04 | 5632 | 11.55 | 11.00 | 9.44 | 17.75 | 6.67 | 29.28 | 73.27 | 97 |
| 3 | 5.05 | 15.51 | 6356 | 11.14 | 10.45 | 9.09 | 16.73 | 6 42 | 27.15 | 68.36 | 121 |
| 4 | 3.27 | 9.45 | 4757 | 6.82 | 6.16 | 5.53 | 9.86 | 3.90 | 15.85 | 41.03 | 150 |
| 5 | 3.37 | 8.52 | 6657 | 6.10 | 5.27 | 4.93 | 8.26 | 3.46 | 12.68 | 33.40 | 229 |
| 6 | 2.62 | 7.55 | 3838 | 5.46 | 4.89 | 4.43 | 7.87 | 3.13 | 12.70 | 33.23 | 161 |
| 7 | .73 | 1.46 | 2494 | 1.06 | .80 | .84 | 1.25 | .59 | 1.85 | 5.38 | 584 |
| 8 | 3.90 | 12.62 | 4374 | 9.13 | 8.63 | 7.45 | 14.00 | 5.27 | 23.28 | 58.85 | 102 |
| 9 | 1.05 | 2.18 | 3250 | 1.58 | 1.22 | 1.26 | 1.91 | .88 | 2.83 | 8.06 | 489 |
| 10 | 2.57 | 5.91 | 6293 | 4.23 | 3.50 | 3.41 | 5.45 | 2.39 | 8.16 | 22.04 | 320 |
| 11 | 3.74 | 9.80 | 6800 | 7.02 | 6.16 | 5.68 | 9.69 | 3.99 | 15.01 | 39.16 | 199 |
| 12 | 6.04 | 16.56 | 9883 | 11.79 | 10.70 | 9.59 | 16.77 | 6.74 | 26.05 | 66.12 | 163 |
| 13 | 2.62 | 9.68 | 2170 | 7.10 | 6.92 | 5.80 | 11.56 | 4.13 | 20.33 | 51.33 | 72 |
| 14 | 2.75 | 10.29 | 2189 | 7.55 | 7.41 | 6.18 | 12.40 | 4.40 | 21.89 | 55.05 | 69 |
| 15 | 1.11 | 3.59 | 1254 | 2.65 | 2.39 | 2.15 | 3.99 | 1.53 | 6.85 | 18.32 | 118 |
| 16 | .91 | 3.11 | 879 | 2.32 | 2.12 | 1.88 | 3.59 | 1.34 | 6.33 | 16.93 | 94 |
| 17 | 2.12 | 8.60 | 1404 | 6.36 | 6.36 | 5.21 | 10.84 | 3.73 | 19.80 | 49.81 | 51 |
| 18 | 3.67 | 13.75 | 2932 | 10.03 | 9.95 | 8.22 | 16.54 | 5.85 | 28.97 | 71.93 | 61 |
| 19 | .11 | .38 | 106 | .29 | .25 | .23 | .44 | .17 | .82 | 2.39 | 122 |
| 20 | .40 | 1.00 | 798 | .74 | .59 | .59 | .97 | .42 | 1.57 | 4.56 | 285 |
| 21 | 5.41 | 18.11 | 5595 | 13.04 | 12.63 | 10.68 | 20.46 | 7.56 | 34.13 | 84.63 | 88 |
| 22 | 5.40 | 16.23 | 7177 | 11.63 | 10.85 | 9.48 | 17.28 | 6.69 | 27.77 | 69.93 | 124 |
| 23 | 6.36 | 19.91 | 7698 | 14.25 | 13.57 | 11.65 | 21.67 | 8.22 | 35.16 | 87.40 | 109 |
| 24 | .31 | .75 | 642 | .56 | .44 | .44 | .72 | .31 | 1.17 | 3.43 | 326 |
| 25 | 6.55 | 19.51 | 8879 | 13.92 | 13.04 | 11.37 | 20.66 | 8.01 | 32.93 | 82.33 | 124 |
| 26 | .34 | 1.06 | 396 | .80 | .68 | .64 | 1.17 | .46 | 2.05 | 5.80 | 144 |

REGION 6

The rivers, streams and tributaries included in this region are shown in figure 9, together with the location of the 11 gaging stations used for deriving the unit-hydrograph parameters. These gaging stations; their USGS number; drainage area, A, above the gaging station; main-channel length, L; and main-channel slope, S; are given in Table 6A. Basin 11, Boneyard Creek at Urbana, is not included in regressions because it is completely urbanized. The basin factors and derived values of unit-hydrograph parameters are, however, included in Table 6A and Table 6B, respectively.

*Basin Factors.* Simple correlation with log A as an independent variable and log L or log S as a dependent variable yields the following:

$$\log L = 0.312 + 0.504 \log A \qquad (1)$$
$$(S_e = 0.095;\ r = 0.982;\ \Sigma\Delta^2 = 0.072)$$

$$\log S = 1.350 - 0.314 \log A \qquad (2)$$
$$(S_e = 0.169;\ r = 0.878;\ \Sigma\Delta^2 = 0.228)$$

More than one-half of $\sum\Delta^2$ ($\Delta^2$ is the square of the difference between the logarithms of given and fitted values of the independent variable) for the relation expressed by equation 1 comes from basins 1 and 9. More than one-half of $\sum\Delta^2$ for the relation given by equation 2 comes from basin 6. No basins yield values of L from equation 1 that exceed by more than 50 percent the corresponding values given in Table 6A. However, the value of S fitted according to equation 2 is more than 50 percent higher for basin 6 than the corresponding values given in Table 6A. This indicates that L and A are much more highly correlated than S and A.

*Derived Unit-Hydrograph Parameters.* The derived unit-hydrograph parameters at each of the 11 gaging stations are given in Table 6B. The step-wise multiple

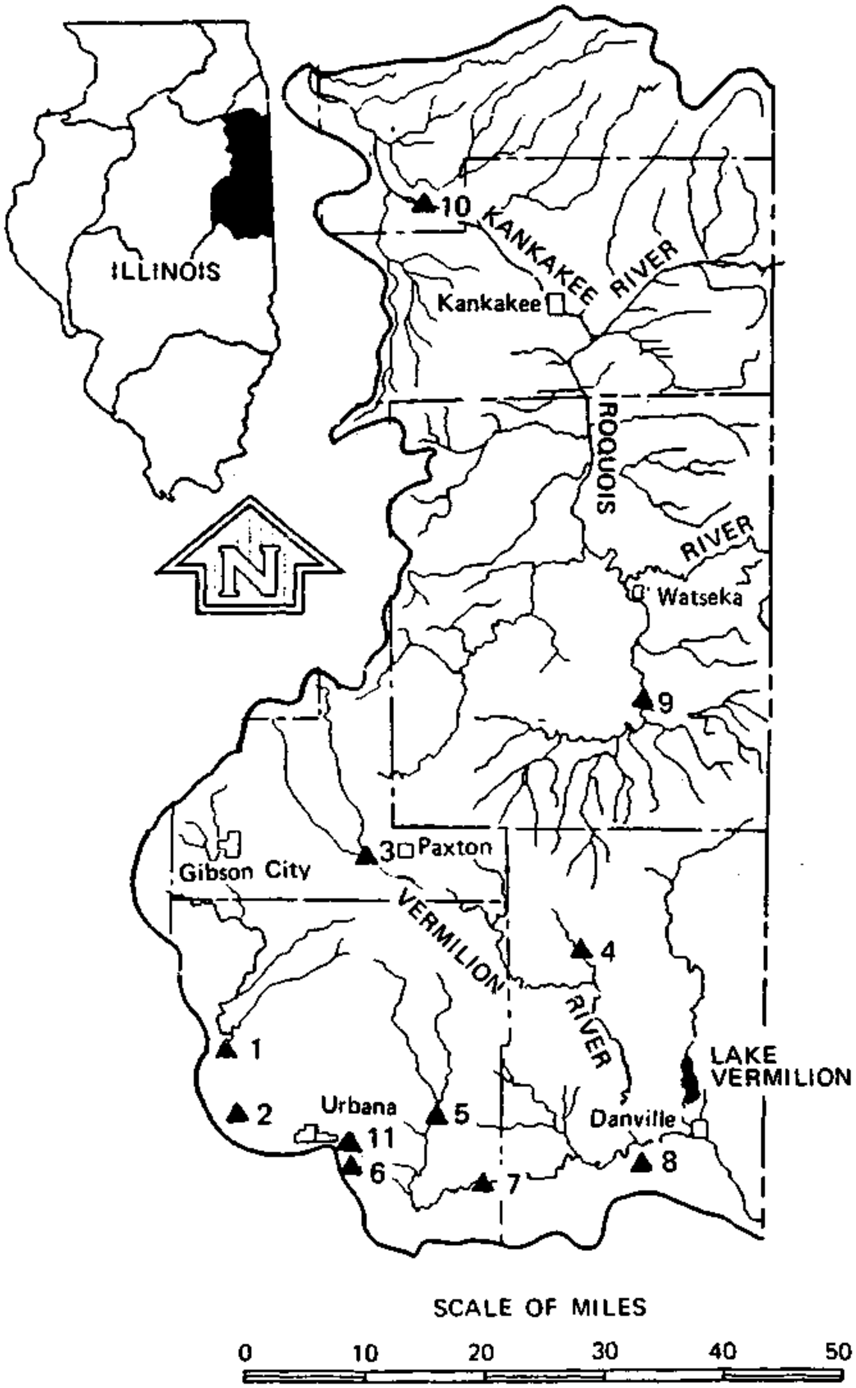



Figure 9. Study basins in region 6

correlation analyses with basins 1 to 10 yielded the following results:

$$\log t_r = -0.143 + 0.399 \log A \qquad (3a)$$
$$(S_e = 0.059;\ r = 0.989)$$

$$\log t_r = -0.247 + 0.231 \log A + 0.334 \log L \qquad (3b)$$
$$(S_e = 0.053;\ R = 0.992)$$

$$\log t_r = -0.152 + 0.224 \log A + 0.309 \log L - 0.064 \log S \qquad (3c)$$
$$(S_e = 0.056;\ R = 0.993)$$

$$\log a = 1.576 - 0.153 \log S \qquad (4a)$$
$$(S_e = 0.149;\ r = 0.342)$$

$$\log a = 2.363 - 0.214 \log A - 0.679 \log S \qquad (4b)$$
$$(S_e = 0.117;\ R = 0.724)$$

$$\log a = 2.328 - 0.247 \log A + 0.071 \log L - 0.670 \log S \qquad (4c)$$
$$(S_e = 0.126;\ R = 0.725)$$

Equations 3b and 4b have been used for computing the fitted $t_r$ and a, i.e., $t_r'$ and a' values.

*Modified Unit-Hydrograph Parameters.* With the fitted values of $t_r$ and a, the remaining 9 unit-hydrograph parameters are modified for any difference between the derived and fitted values of the two parameters. The values of $t_r'$ and a' and 9 modified parameters are given in Table 6C. The significant regression equations obtained with the step-wise multiple correlation analyses applied to the unit-hydrograph parameter as a dependent variable and the basin factors as the independent variables are as follows (the $S_e$ and R refer to the estimate of standard error and the multiple correlation coefficient from the regression between log-transformed variables, respectively):

$$t_r' = 0.566\ A^{0.231}\ L^{0.334} \qquad (5)$$

$$a' = 230.4\ A^{-0.214}\ S^{-0.679} \qquad (6)$$

$$t_p = 1.668\ A^{0.490} \qquad (7)$$
$$(S_e = 0.046;\ r = 0.996)$$

$$U_p = 261.9\ A^{0.505} \tag{8}$$
$$(S_e = 0.082;\ r = 0.987)$$

$$t_{.75} = 1.228\ A^{0.485} \tag{9}$$
$$(S_e = 0.055;\ r = 0.993)$$

$$d_{.75} = 1.020\ A^{0.534} \tag{10}$$
$$(S_e = 0.062;\ r = 0.993)$$

$$t_{.50} = 0.907\ A^{0.494} \tag{11}$$
$$(S_e = 0.038;\ r = 0.997)$$

$$d_{.50} = 1.888\ A^{0.517} \tag{12}$$
$$(S_e = 0.063;\ r = 0.992)$$

$$t_{.25} = 0.601\ A^{0.508} \tag{13}$$
$$(S_e = 0.047;\ r = 0.996)$$

$$d_{.25} = 3.320\ A^{0.496} \tag{14}$$
$$(S_e = 0.088;\ r = 0.984)$$

$$t_b = 9.151\ A^{0.463} \tag{15}$$
$$(S_e = 0.049;\ r = 0.994)$$

*Fitted Unit-Hydrograph Parameters.* These parameters, obtained from equations 5 through 15, are given in Table 6D. All the equations, except $t_r$' and a', use only A as an independent variable.

The 10 basins are summarized below in terms of the derived and fitted values of the unit-hydrograph peak from Table 6C and 6D, respectively.

fitted $U_p$ within ± 10% of derived $U_p$ 7 basins

fitted $U_p$ within ± 25% of derived $U_p$ 9 basins

| remaining 1 basin: | number | fitted/derived $U_p$ |
|---|---|---|
| | A | 0.658 |

TABLE 6. Unit-Hydrograph Parameters for Region 6

A. Basin Factors

| No. | Stream and Gaging Station | USGS No. | Area | Length | Slope |
|---|---|---|---|---|---|
| 1 | Sangamon River at Mahomet | 05571000 | 362.00 | 56.41 | 3.59 |
| 2 | Kaskaskia Ditch at Bondville | 05590000 | 12.40 | 5.51 | 17.16 |
| 3 | Big Four Ditch Tributary near Paxton | 03336100 | 1.05 | 2.16 | 21.01 |
| 4 | Bluegrass Creek at Potomac | 03336500 | 35.00 | 12.77 | 6.92 |
| 5 | Salt Fork near St. Joseph | 03336900 | 134.00 | 24.28 | 5.49 |
| 6 | West Branch of Salt Fork at Urbana | 03337500 | 68.00 | 14.52 | 2.59 |
| 7 | Salt Fork near Homer | 03338000 | 340.00 | 44.60 | 3.01 |
| 8 | Salt Fork Tributary near Catlin | 03338100 | 2.20 | 3.40 | 15.81 |
| 9 | Sugar Creek at Milford | 05525500 | 446.00 | 32.02 | 4.86 |
| 10 | Terry Creek near Custer Park | 05526500 | 12.10 | 8.04 | 11.93 |
| 11 | Boneyard Creek at Urbana | 03337000 | 4.46 | 3.73 | 12.51 |

B. Derived Unit-Hydrograph Parameters

| No. | $t_r$ | $t_p$ | $U_p$ | $t_{.75}$ | $d_{.75}$ | $t_{.50}$ | $d_{.50}$ | $t_{.25}$ | $d_{.25}$ | $t_b$ | a |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 8.00 | 32.00 | 5600 | 24.80 | 20.40 | 19.00 | 37.00 | 14.00 | 60.00 | 130.00 | 30 |
| 2 | 2.00 | 5.00 | 900 | 3.80 | 4.00 | 3.00 | 7.70 | 2.30 | 12.00 | 29.00 | 20 |
| 3 | .67 | 1.76 | 280 | 1.26 | 1.07 | .98 | 1.83 | .59 | 3.20 | 9.00 | 25 |
| 4 | 3.00 | 8.00 | 2400 | 6.00 | 5.00 | 4.80 | 8.50 | 4.00 | 12.00 | 40.00 | 50 |
| 5 | 6.00 | 19.00 | 2700 | 12.90 | 15.10 | 9.70 | 26.70 | 6.30 | 43.50 | 100.00 | 20 |
| 6 | 4.00 | 13.00 | 2050 | 8.50 | 11.00 | 7.00 | 16.00 | 5.00 | 28.50 | 72.00 | 50 |
| 7 | 8.00 | 28.00 | 4800 | 19.40 | 26.60 | 16.00 | 41.70 | 11.80 | 59.00 | 120.00 | 25 |
| 8 | 1.00 | 2.70 | 400 | 1.85 | 1.50 | 1.35 | 2.90 | .85 | 5.00 | 12.70 | 25 |
| 9 | 6.00 | 36.00 | 5600 | 25.00 | 26.00 | 19.00 | 45.00 | 12.00 | 70.00 | 160.00 | 20 |
| 10 | 2.00 | 6.00 | 700 | 5.00 | 4.20 | 3.20 | 8.00 | 2.20 | 15.20 | 34.00 | 30 |
| 11 | 1.00 | 2.33 | 1200 | 2.00 | 1.30 | 1.78 | 2.20 | 1.43 | 3.17 | 12.00 | 250 |

C. Modified Unit-Hydrograph Parameters Using Fitted $t_r$ and a

| No. | $t_r'$ | $t_p$ | $U_p$ | $t_{.75}$ | $d_{.75}$ | $t_{.50}$ | $d_{.50}$ | $t_{.25}$ | $d_{.25}$ | $t_b$ | a' |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 8.48 | 32.24 | 5586 | 25.04 | 20.64 | 19.24 | 37.36 | 14.24 | 60.48 | 130.48 | 27 |
| 2 | 1.79 | 4.89 | 904 | 3.69 | 3.89 | 2.89 | 7.54 | 2.19 | 11.79 | 28.79 | 20 |
| 3 | .74 | 1.80 | 277 | 1.30 | 1.11 | 1.02 | 1.88 | .63 | 3.27 | 9.07 | 29 |
| 4 | 3.01 | 8.01 | 2399 | 6.01 | 5.01 | 4.81 | 8.51 | 4.01 | 12.01 | 40.01 | 29 |
| 5 | 5.09 | 18.54 | 2722 | 12.44 | 14.64 • | 9.24 | 26.02 | 5.84 | 42.59 | 99.09 | 25 |
| 6 | 3.66 | 12.83 | 2066 | 8.33 | 10.83 | 6.83 | 15.75 | 4.83 | 28.16 | 71.66 | 49 |
| 7 | 7.68 | 27.84 | 4810 | 19.24 | 26.44 | 15.84 | 41.46 | 11.64 | 58.68 | 119.68 | 32 |
| 8 | 1.02 | 2.71 | 399 | 1.86 | 1.51 | 1.36 | 2.92 | .86 | 5.02 | 12.72 | 30 |
| 9 | 7.37 | 36.68 | 5571 | 25.68 | 26.68 | 19.68 | 46.03 | 12.68 | 71.37 | 161.37 | 21 |
| 10 | 2.02 | 6.01 | 699 | 5.01 | 4.21 | 3.21 | 8.01 | 2.21 | 15.22 | 34.02 | 25 |

D. Fitted Unit-Hydrograph Parameters

| No. | $t_r$ | $t_p$ | $U_p$ | $t_{.75}$ | $d_{.75}$ | $t_{.50}$ | $d_{.50}$ | $t_{.25}$ | $d_{.25}$ | $t_b$ | a |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 8.48 | 29.98 | 5144 | 21.37 | 23.67 | 16.68 | 39.78 | 11.97 | 61.68 | 139.60 | 27 |
| 2 | 1.79 | 5.73 | 934 | 4.16 | 3.91 | 3.15 | 6.94 | 2.16 | 11.57 | 29.32 | 20 |
| 3 | .74 | 1.71 | 268 | 1.26 | 1.03 | .93 | 1.94 | .62 | 3.40 | 9.36 | 29 |
| 4 | 3.01 | 9.53 | 1579 | 6.88 | 6.80 | 5.26 | 11.88 | 3.65 | 19.36 | 47.38 | 29 |
| 5 | 5.09 | 18.42 | 3113 | 13.20 | 13.93 | 10.21 | 23.79 | 7.23 | 37.68 | 88.16 | 25 |
| 6 | 3.66 | 13.20 | 2209 | 9.50 | 9.70 | 7.30 | 16.75 | 5.12 | 26.91 | 64.42 | 49 |
| 7 | 7.68 | 28.65 | 4909 | 20.43 | 22.53 | 15.94 | 37.92 | 11.42 | 58.91 | 133.75 | 32 |
| 8 | 1.02 | 2.45 | 390 | 1.80 | 1.55 | 1.34 | 2.84 | .90 | 4.91 | 13.18 | 30 |
| 9 | 7.37 | 33.21 | 5716 | 23.64 | 26.46 | 18.50 | 44.31 | 13.31 | 68.40 | 153.75 | 21 |
| 10 | 2.02 | 5.66 | 923 | 4.11 | 3.86 | 3.11 | 6.86 | 2.13 | 11.43 | 28.99 | 25 |

## REGION 7

The rivers, streams and tributaries included in this region are shown in figure 10, together with the location of the 19 gaging stations used for deriving the unit-hydrograph parameters. These gaging stations; their USGS number; drainage area, A, above the gaging station; main-channel length, L; and main-channel slope, S; are given in Table 7A.

*Basin Factors.* Simple correlation with log A as an independent variable and log L or log S as a dependent variable yields the following:

$$\log L = 0.217 + 0.587 \log A \qquad (1)$$
$$(S_e = 0.088;\ r = 0.992;\ \Sigma\Delta^2 = 0.132)$$

$$\log S = 1.267 - 0.291 \log A \qquad (2)$$
$$(S_e = 0.251;\ r = 0.804;\ \Sigma\Delta^2 = 1.070)$$

About one-half of $\sum\Delta^2$ ($\Delta^2$ is the square of the difference between the logarithms of given and fitted values of the independent variable) for the relation expressed by equation 1 comes from basins 7, 10 and 11; and about one-half of $\sum\Delta^2$ for the relation given by equation 2 comes from basins 5, 9, 11 and 17. No basins yield values of L from equation 1 that exceed by more than 50 percent the corresponding values given in Table 7A. However, the values of S fitted according to equation 2 are more than 50 percent lower for basins 5 and 11, and more than 50 percent higher for basins 1, 9, 10, 14 and 17 than the corresponding values given in Table 7A. This indicates that L and A are much more highly correlated than S and A.

*Derived Unit-Hydrograph Parameters.* The derived unit-hydrograph parameters at each of the 19 gaging stations are given in Table 7B. The step-wise multiple correlation analyses yielded the following results:

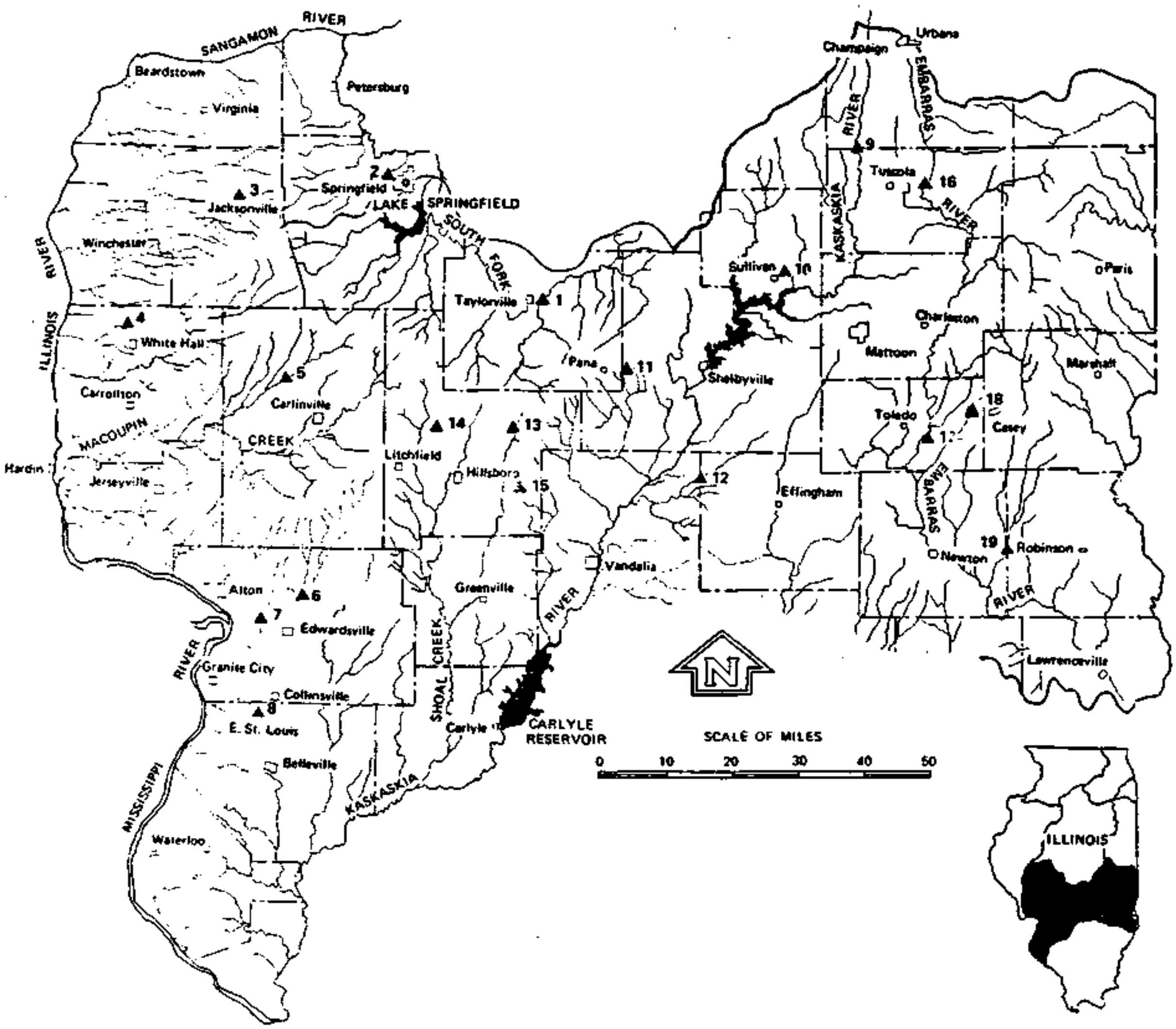



Figure 10. Study basins in region 7

$$\log t_r = -0.282 + 0.429 \log A \qquad (3a)$$
$$(S_e = 0.091;\ r = 0.984)$$

$$\log t_r = 0.084 + 0.345 \log A - 0.290 \log S \qquad (3b)$$
$$(S_e = 0.057;\ R = 0.994)$$

$$\log t_r = 0.103 + 0.507 \log A - 0.262 \log L - 0.259 \log S \qquad (3c)$$
$$(S_e = 0.054;\ R = 0.995)$$

$$\log a = 1.743 + 0.183 \log L \qquad (4a)$$
$$(S_e = 0.305;\ r = 0.383)$$

$$\log a = 0.293 + 0.689 \log L + 1.072 \log S \qquad (4b)$$
$$(S_e = 0.104;\ R = 0.952)$$

$$\log a = 0.294 - 0.068 \log A + 0.794 \log L + 1.054 \log S \qquad (4c)$$
$$(S_e = 0.107;\ R = 0.952)$$

Equations 3b and 4b have been used for computing the fitted $t_r$ and a, i.e., $t_r'$ and a' values.

*Modified Unit-Hydrograph Parameters.* With the fitted values of $t_r$ and a. the remaining 9 unit-hydrograph parameters are -modified for any difference between the derived and fitted values of the two parameters. The values of $t_r'$ and a' and 9 modified parameters are given in Table 7C. The significant regression equations obtained with the step-wise multiple correlation analyses applied to the unit-hydrograph parameter as a dependent variable and the basin factors as the independent variables are as follows (the $S_e$ and R refer to the estimate of standard error and the multiple correlation coefficient from the regression between log-transformed variables, respectively):

$$t_r' = 1.215\ A^{0.345}\ S^{-0.290} \qquad (5)$$

$$a' = 1.965\ L^{0.689}\ S^{1.072} \qquad (6)$$

$$t_p = 3.950\ A^{0.403}\ S^{-0.380} \qquad (7)$$
$$(S_e = 0.027;\ R = 0.999)$$

$$U_p = 55.22\ A^{0.473}\ L^{0.279}\ S^{0.608} \tag{8}$$
$$(S_e = 0.078;\ R = 0.992)$$

$$t_{.75} = 2.849\ A^{0.406}\ S^{-0.393} \tag{9}$$
$$(S_e = 0.053;\ R = 0.997)$$

$$d_{.75} = 3.365\ A^{0.409}\ S^{-0.486} \tag{10}$$
$$(S_e = 0.053;\ R = 0.997)$$

$$t_{.50} = 2.137\ A^{0.416}\ S^{-0.371} \tag{11}$$
$$(S_e = 0.055;\ R = 0.996)$$

$$d_{.50} = 7.326\ A^{0.378}\ S^{-0.576} \tag{12}$$
$$(S_e = 0.065;\ R = 0.995)$$

$$t_{.25} = 1.323\ A^{0.428}\ S^{-0.327} \tag{13}$$
$$(S_e = 0.067;\ R = 0.995)$$

$$d_{.25} = 15.53\ A^{0.351}\ S^{-0.653} \tag{14}$$
$$(S_e = 0.087;\ R = 0.992)$$

$$t_b = 31.92\ A^{0.364}\ S^{-0.573} \tag{15}$$
$$(S_e = 0.092;\ R = 0.990)$$

*Fitted Unit-Hydrograph Parameters.* These parameters, obtained from equations 5 through 15, are given in Table 7D. All the equations, except a' and U , use A and S as independent variables.

The 19 basins are summarized below in terms of the derived and fitted values of the unit-hydrograph peak from Tables 7C and 7D, respectively.

fitted $U_p$ within ± 10% of derived $U_p$ 9 basins

fitted $U_p$ within ± 25% of derived $U_p$ 16 basins

| remaining 3 basins: | number | fitted/derived $U_p$ |
|---|---|---|
| | 3 | 1.256 |
| | 6 | 1.281 |
| | 8 | 0.730 |

TABLE 7. Unit-Hydrograph Parameters for Region 7

A. Basin Factors

| No. | Stream and Gaging Station | USGS No. | Area | Length | Slope |
|---|---|---|---|---|---|
| 1 | Flat Branch near Taylorville | 05574500 | 276.00 | 47.49 | 2.01 |
| 2 | Spring Creek at Springfield | 05577500 | 107.00 | 29.37 | 5.39 |
| 3 | N.F. Mauvaise Terre Cr.nr Jacksonville | 05586000 | 29.10 | 13.16 | 9.03 |
| 4 | Hurricane Creek near Roodhouse | 05586500 | 2.30 | 3.30 | 24.29 |
| 5 | Otter Creek near Palmyra | 05586800 | 61.10 | 14.99 | 11.30 |
| 6 | Cahokia Cr. Tributary #2 near Carpenter | 05587850 | .45 | .92 | 42.50 |
| 7 | Indian Creek at Wanda | 05588000 | 36.70 | 20.89 | 7.92 |
| 8 | Canteen Creek at Caseyville | 05589500 | 22.60 | 10.93 | 11.09 |
| 9 | Kaskaskia River near Pesotum | 05590400 | 107.00 | 23.59 | 2.46 |
| 10 | Asa Creek near Sullivan | 05591500 | 8.05 | 4.20 | 5.23 |
| 11 | Mud Creek near Tower Hill | 05592025 | .20 | .85 | 63.89 |
| 12 | Wolf Creek near Beecher City | 05592300 | 47.90 | 16.56 | 6.60 |
| 13 | Hurricane Creek Tributary near Witt | 05592700 | .14 | .44 | 27.09 |
| 14 | Blue Grass Creek near Raymond | 05593600 | 17.30 | 6.83 | 4.28 |
| 15 | East Fork Shoal Creek near Coffeen | 05593900 | 55.50 | 20.20 | 5.54 |
| 16 | Embarras River near Camargo | 03343400 | 186.03 | 27.27 | 2.96 |
| 17 | Embarras River Tributary near Greenup | 03344250 | .08 | .38 | 10.51 |
| 18 | Range Creek near Casey | 03344500 | 7.61 | 4.58 | 15.73 |
| 19 | North Fork Embarras River near Oblong | 03346000 | 319.00 | 51.21 | 4.33 |

B. Derived Unit-Hydrograph Parameters

| No. | $t_r$ | $t_p$ | $U_p$ | $t_{.75}$ | $d_{.75}$ | $t_{.50}$ | $d_{.50}$ | $t_{.25}$ | $d_{.25}$ | $t_b$ | a |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 7.00 | 29.50 | 3450 | 21.00 | 26.00 | 17.50 | 43.00 | 13.00 | 71.00 | 159.00 | 50 |
| 2 | 4.00 | 14.00 | 3600 | 9.70 | 10.10 | 7.80 | 16.10 | 5.30 | 25.30 | 64.00 | 120 |
| 3 | 2.00 | 7.00 | 1700 | 5.00 | 5.30 | 4.00 | 8.60 | 2.70 | 14.60 | 42.00 | 100 |
| 4 | .67 | 1.75 | 750 | .80 | .95 | .63 | 1.60 | .47 | 2.45 | 4.67 | 180 |
| 5 | 3.00 | 8.00 | 3200 | 6.30 | 5.40 | 5.30 | 9.50 | 3.50 | 16.70 | 43.00 | 160 |
| 6 | .33 | .67 | 280 | .48 | .47 | .42 | .73 | .35 | 1.40 | 4.00 | 90 |
| 7 | 2.00 | 8.00 | 2200 | 6.20. | 5.10 | 5.00 | 8.60 | 3.50 | 14.40 | 44.00 | 200 |
| 8 | 2.00 | 5.00 | 2750 | 3.60 | 3.60 | 3.00 | 4.80 | 2.40 | 6.60 | 20.00 | 120 |
| 9 | 4.00 | 18.00 | 2500 | 13.00 | 13.30 | 10.50 | 20.40 | 7.80 | 38.50 | 95.00 | 50 |
| 10 | 2.00 | 5.00 | 500 | 3.60 | 3.60 | 3.20 | 7.30 | 2.40 | 14.90 | 38.00 | 50 |

B. Derived Unit-Hydrograph Parameters (continued)

| No. | $t_r$ | $t_p$ | $U_p$ | $t_{.75}$ | $d_{.75}$ | $t_{.50}$ | $d_{.50}$ | $t_{.25}$ | $d_{.25}$ | $t_b$ | a |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 11 | .17 | .42 | 400 | .30 | .22 | .24 | .32 | .19 | .50 | 1.45 | 180 |
| 12 | 3.00 | 9.00 | 2600 | 6.60 | 6.20 | 5.50 | 10.10 | 4.00 | 16.10 | 41.00 | 120 |
| 13 | .25 | .50 | 140 | .38 | .25 | .30 | .42 | .18 | .70 | 2.17 | 30 |
| 14 | 2.00 | 7.00 | 1100 | 5.10 | 5.10 | 4.20 | 8.10 | 2.70 | 12.90 | 37.00 | 50 |
| 15 | 3.00 | 12.00 | 2000 | 8.50 | 9.00 | 6.10 | 15.20 | 4.00 | 24.00 | 50.00 | 80 |
| 16 | 5.00 | 21.00 | 3000 | 13.50 | 19.40 | 10.60 | 32.70 | 7.00 | 55.00 | 121.00 | 50 |
| 17 | .25 | .58 | 50 | .40 | .40 | .29 | .81 | .19 | 1.52 | 3.08 | 10 |
| 18 | 1.00 | 3.25 | 1200 | 2.35 | 2.20 | 1.85 | 3.60 | 1.15 | 5.30 | 13.50 | 100 |
| 19 | 5.00 | 22.00 | 7000 | 16.80 | 14.00 | 13.80 | 23.80 | 9.90 | 40.80 | 92.00 | 120 |

C. Modified Unit-Hydrograph Parameters Using Fitted $t_r$ and a

| No. | $t_r'$ | $t_p$ | $U_p$ | $t_{.75}$ | $d_{.75}$ | $t_{.50}$ | $d_{.50}$ | $t_{.25}$ | $d_{.25}$ | $t_b$ | a |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 6.88 | 29.44 | 3457 | 20.94 | 25.94 | 17.44 | 42.91 | 12.94 | 70.88 | 158.88 | 59 |
| 2 | 3.73 | 13.87 | 3633 | 9.57 | 9.97 | 7.67 | 15.90 | 5.17 | 25.03 | 63.73 | 123 |
| 3 | 2.05 | 7.03 | 1693 | 5.03 | 5.33 | 4.03 | 8.64 | 2.73 | 14.65 | 42.05 | 123 |
| 4 | .64 | 1.74 | 753 | .79 | .94 | .62 | 1.58 | .46 | 2.43 | 4.64 | 137 |
| 5 | 2.48 | 7.74 | 3288 | 6.04 | 5.14 | 5.04 | 9.11 | 3.24 | 16.18 | 42.48 | 171 |
| 6 | .31 | .66 | 281 | .47 | .46 | .41 | .72 | .34 | 1.38 | 3.98 | 103 |
| 7 | 2.31 | 8.15 | 2154 | 6.35 | 5.25 | 5.15 | 8.83 | 3.65 | 14.71 | 44.31 | 147 |
| 8 | 1.77 | 4.89 | 2780 | 3.49 | 3.49 | 2.89 | 4.63 | 2.29 | 6.37 | 19.77 | 135 |
| 9 | 4.68 | 18.34 | 24.58 | 13.34 | 13.64 | 10.84 | 20.91 | 8.14 | 39.18 | 95.68 | 46 |
| 10 | 1.54 | 4.77 | 514 | 3.37 | 3.37 | 2.97 | 6.96 | 2.17 | 14.44 | 37.54 | 31 |
| 11 | .21 | .44 | 394 | .32 | .24 | .26 | .35 | .21 | .54 | 1.49 | 151 |
| 12 | 2.67 | 8.83 | 2634 | 6.43 | 6.03 | 5.33 | 9.85 | 3.83 | 15.77 | 40.67 | 103 |
| 13 | .24 | .49 | 140 | .37 | .24 | .29 | .41 | .17 | .69 | 2.16 | 38 |
| 14 | 2.13 | 7.06 | 1095 | 5.16 | 5.16 | 4.26 | 8.20 | 2.76 | 13.03 | 37.13 | 35 |
| 15 | 2.95 | 11.98 | 2004 | 8.48 | 8.98 | 6.08 | 15.16 | 3.98 | 23.95 | 49.95 | 98 |
| 16 | 5.37 | 21.18 | 2977 | 13.68 | 19.58 | 10.78 | 32.98 | 7.18 | 55.37 | 121.37 | 61 |
| 17 | .26 | .58 | 49 | .40 | .40 | .29 | .82 | .19 | 1.53 | 3.09 | 13 |
| 18 | 1.10 | 3.30 | 1189 | 2.40 | 2.25 | 1.90 | 3.68 | 1.20 | 5.40 | 13.60 | 108 |
| 19 | 5.79 | 22.40 | 6887 | 17.20 | 14.40 | 14.20 | 24.39 | 10.30 | 41.59 | 92.79 | 142 |

D. Fitted Unit-Hydrograph Parameters

| No. | $t_r$ | $t_p$ | $U_p$ | $t_{.75}$ | $d_{.75}$ | $t_{.50}$ | $d_{.50}$ | $t_{.25}$ | $d_{.25}$ | $t_b$ | a |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 6.88 | 29.23 | 3538 | 21.18 | 23.92 | 17.06 | 41.06 | 11.65 | 70.59 | 165.85 | 59 |
| 2 | 3.73 | 13.71 | 3599 | 9.78 | 10.05 | 7.98 | 16.26 | 5.62 | 26.59 | 66.72 | 123 |
| 3 | 2.05 | 6.67 | 2126 | 4.71 | 4.59 | 3.84 | 7.39 | 2.72 | 12.03 | 30.88 | 123 |
| 4 | .64 | 1.65 | 793 | 1.14 | 1.00 | 0.93 | 1.60 | .67 | 2.59 | 6.95 | 137 |
| 5 | 2.48 | 8.26 | 3588 | 5.82 | 5.58 | 4.80 | 8.59 | 3.47 | 13.47 | 35.59 | 171 |
| 6 | .31 | .69 | 360 | .47 | .39 | .38 | .63 | .28 | 1.01 | 2.78 | 103 |
| 7 | 2.31 | 7.70 | 2492 | 5.45 | 5.38 | 4.44 | 8.69 | 3.14 | 14.21 | 36.23 | 147 |
| 8 | 1.77 | 5.57 | 2029 | 3.92 | 3.75 | 3.20 | 5.96 | 2.28 | 9.63 | 24.04 | 135 |
| 9 | 4.68 | 18.47 | 2102 | 13.32 | 14.71 | 10.68 | 25.54 | 7.27 | 44.38 | 104.59 | 46 |
| 10 | 1.54 | 4.89 | 604 | 3.46 | 3.54 | 2.75 | 6.22 | 1.88 | 10.95 | 26.44 | 31 |
| 11 | .21 | .43 | 308 | .29 | .23 | .23 | .36 | .17 | .58 | 1.64 | 151 |
| 12 | 2.67 | 9.18 | 2372 | 6.52 | 6.56 | 5.30 | 10.68 | 3.73 | 17.58 | 44.32 | 103 |
| 13 | .24 | .51 | 128 | .35 | .30 | .28 | .52 | .19 | .90 | 2.35 | 38 |
| 14 | 2.13 | 7.18 | 879 | 5.11 | 5.33 | 4.08 | 9.32 | 2.78 | 16.32 | 39.20 | 35 |
| 15 | 2.95 | 10.41 | 2416 | 7.41 | 7.58 | 6.01 | 12.49 | 4.21 | 20.75 | 51.70 | 98 |
| 16 | 5.37 | 21.52 | 3181 | 15.50 | 16.87 | 12.54 | 28.30 | 8.67 | 47.75 | 115.07 | 61 |
| 17 | .26 | .58 | 53 | .41 | .38 | .31 | .73 | .21 | 1.38 | 3.30 | 13 |
| 18 | 1.10 | 3.14 | 1176 | 2.20 | 2.02 | 1.79 | 3.23 | 1.28 | 5.23 | 13.78 | 108 |
| 19 | 5.79 | 23.15 | 6168 | 16.61 | 17.48 | 13.63 | 27.88 | 9.64 | 44.99 | 112.62 | 142 |

## REGION 8

The rivers, streams and tributaries included in this region are shown in figure 11. together with the location of the 17 gaging stations used for deriving the unit-hydrograph parameters. These gaging stations; their USGS number; drainage area, A, above the gaging station; main-channel length, L; and main-channel slope, S; are given in Table 8A.

*Basin Factors.* Simple correlation with log A as an independent variable and log L or log S as a dependent variable yields the following:

$$\log L = 0.245 + 0.579 \log A \quad (1)$$

$$(S_e = 0.067;\ r = 0.996;\ \Sigma\Delta^2 = 0.068)$$

$$\log S = 1.738 - 0.514 \log A \quad (2)$$

$$(S_e = 0.179;\ r = 0.965;\ \Sigma\Delta^2 = 0.482)$$

More than one-half of $\sum\Delta^2$ ($\Delta^2$ is the square of thp ditference between the logarithms of given and fitted values of the independent variable) for the relation expressed by equation 1 comes from basins 1 and 4. More than one-half of $\sum\Delta^2$ for the relation given by equation 2 comes from basins 6 and 15. No basins yield values of L from equation 1 that exceed by more than 50 percent the corresponding values given in Table 8A. However, the values of S fitted according to equation 2 are more than 50 percent lower for basin 15, and more than 50 percent higher for basins 6 and 11 than the corresponding values given in Table 8A. Both L and A, and S and A, are highly correlated.

*Derived Unit-Hydrograph Parameters.* The derived unit-hydrograph parameters at each of the 17 gaging stations are given in Table 8B. The step-wise multiple correlations analyses yielded the following results:

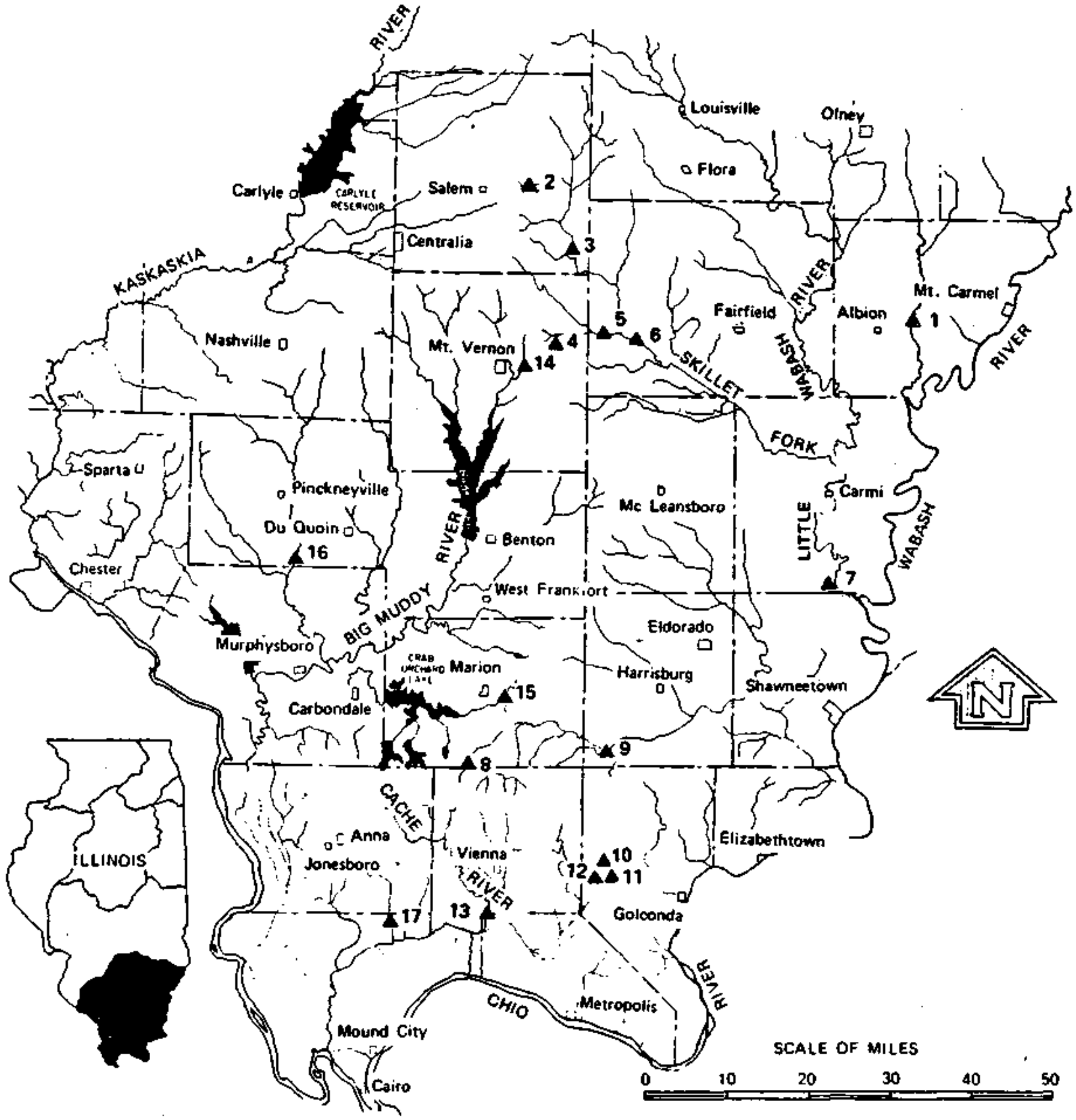



Figure 11. Study basins in region 8

$$\log t_r = -0.245 + 0.473 \log A \tag{3a}$$
$$(S_e = 0.047;\ r = 0.997)$$

$$\log t_r = -0.324 + 0.287 \log A + 0.322 \log L \tag{3b}$$
$$(S_e = 0.043;\ R = 0.998)$$

$$\log t_r = -0.232 + 0.245 \log A + 0.345 \log L - 0.056 \log S \tag{3c}$$
$$(S_e = 0.044;\ R = 0.998)$$

$$\log a = 1.246 + 0.444 \log S \tag{4a}$$
$$(S_e = 0.095;\ r = 0.955)$$

$$\log a = 0.886 + 0.111 \log A + 0.645 \log S \tag{4b}$$
$$(S_e = 0.090;\ R = 0.962)$$

$$\log a = 0.934 + 0.317 \log A - 0.338 \log L + 0.665 \log S \tag{4c}$$
$$(S_e = 0.092;\ R = 0.965)$$

Equations 3b and 4b have been used for computing the fitted $t_r$ and a, i.e., $t_r'$ and a' values.

*Modified Unit-Hydrograph Parameters.* With the fitted values of $t_r$ and a, the remaining 9 unit-hydrograph parameters are modified for any difference between the derived and fitted values of the two parameters. The values of $t_r'$ and a' and 9 modified parameters are given in Table 8C. The significant regression equations obtained with the step-wise multiple correlation analyses applied to the unit-hydrograph parameter as a dependent variable and the basin factors as the independent variables are as follows (the $S_e$ and R refer to the estimate of standard error and the multiple correlation coefficient from the regression between log-trans formed variables, respectively):

$$t_r' = 0.475\ A^{0.287}\ L^{0.322} \tag{5}$$

$$a' = 7.694\ A^{0.111}\ S^{0.645} \tag{6}$$

$$t_p = 8.318\ A^{0.329}\ S^{-0.416} \tag{7}$$
$$(S_e = 0.058;\ R = 0.997)$$

$$U_p = 106.0\ A^{0.547}\ S^{0.339} \tag{8}$$
$$(S_e = 0.090;\ R = 0.984)$$

$$t_{.75} = 5.703\ A^{0.327}\ S^{-0.391} \tag{9}$$
$$(S_e = 0.038;\ R = 0.999)$$

$$d_{.75} = 5.005\ A^{0.394}\ S^{-0.446} \tag{10}$$
$$(S_e = 0.089;\ R = 0.994)$$

$$t_{.50} = 4.218\ A^{0.334}\ S^{-0.367} \tag{11}$$
$$(S_e = 0.037;\ R = 0.999)$$

$$d_{.50} = 6.334\ A^{0.434}\ S^{-0.387} \tag{12}$$
$$(S_e = 0.088;\ R = 0.995)$$

$$t_{.25} = 1.687\ A^{0.104}\ L^{0.460}\ S^{-0.307} \tag{13}$$
$$(S_e = 0.053;\ R = 0.997)$$

$$d_{.25} = 10.02\ A^{0.431}\ S^{-0.387} \tag{14}$$
$$(S_e = 0.092;\ R = 0.994)$$

$$t_b = 9.877\ A^{0.516}\ S^{-0.133} \tag{15}$$
$$(S_e = 0.087;\ R = 0.994)$$

*Fitted Unit-Hydrograph Parameters.* These parameters, obtained from equations 5 through 15, are given in Table 8D. All the equations, except $t_r'$ and $t_{.25}$, use A and S as independent variables.

The 17 basins are summarized below in terms of the derived and fitted values of the unit-hydrograph peak from Table 8C and 8D, respectively.

fitted $U_p$ within ± 10% of derived $U_p$ 9 basins

fitted $U_p$ within ± 25% of derived $U_p$ 13 basins

remaining 4 basins:

| number | fitted/derived $U_p$ |
|---|---|
| 1 | 1.455 |
| 6 | 0.689 |
| 9 | 1.329 |
| 13 | 1.264 |

TABLE 8. Unit Hydrograph Parameters for Region 5

A. Basin Factors

| No. | Stream and Gaging Station | USGS No. | Area | Length | Slope |
|---|---|---|---|---|---|
| 1 | Bonpas Creek at Browns | 03378000 | 228.00 | 36.26 | 2.85 |
| 2 | Dums Creek Tributary near Iuka | 03380300 | .08 | .40 | 98.74 |
| 3 | Skillet Creek near Iuka | 03380350 | 208.00 | 31.86 | 2.78 |
| 4 | White Feather Creek near Marlow | 03380450 | .43 | 1.11 | 87.65 |
| 5 | Horse Creek near Keenes | 03380475 | 97.20 | 26.38 | 4.07 |
| 6 | Skillet Fork at Wayne City | 03380500 | 464.00 | 59.52 | 1.90 |
| 7 | L. Wabash River Trib. near New Haven | 03381600 | .16 | .62 | 89.76 |
| 8 | L. Saline Creek Trib. near Goreville | 03382025 | .52 | 1.13 | 75.50 |
| 9 | S. F. Saline River near Carrier Mills | 03382100 | 147.00 | 32.22 | 4.26 |
| 10 | Hayes Creek at Glendale | 03385000 | 19.10 | 12.01 | 21.44 |
| 11 | Lake Glendale Inlet near Dixon Springs | 03385500 | 1.05 | 1.86 | 145.20 |
| 12 | Sugar Creek near Dixon Springs | 03386500 | 9.93 | 6.25 | 25.24 |
| 13 | Cache River at Forman | 03612000 | 244.00 | 49.31 | 2.69 |
| 14 | Sevenmile Creek near Mt. Vernon | 05595800 | 21.10 | 7.43 | 14.52 |
| 15 | Crab Orchard Creek near Marion | 05597500 | n.70 | 11.56 | 8.08 |
| 16 | Beaucoup Creek near Matthews | 05599000 | 292.00 | 51.44 | 2.64 |
| 17 | Big Creek near Wetaug | 05600000 | 32.20 | 17.92 | 11.30 |

B. Derived Unit-Hydrograph Parameters

| No. | $t_r$ | $t_p$ | $U_p$ | $t_{.75}$ | $d_{.75}$ | $t_{.50}$ | $d_{.50}$ | $t_{.25}$ | $d_{.25}$ | $t_b$ | a |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 8.00 | 40.00 | 2000 | 26.00 | 40.00 | 20.00 | 68.00 | 12.80 | 104.00 | 180.00 | 25 |
| 2 | .17 | .54 | 120 | .42 | .23 | .34 | .37 | .22 | .60 | 1.63 | 120 |
| 3 | 7.00 | 29.00 | 3000 | 20.00 | 24.00 | 15.00 | 40.00 | 9.00 | 61.00 | 125.00 | 30 |
| 4 | .42 | 1.08 | 300 | .83 | .50 | .60 | .82 | .33 | 1.30 | 2.75 | 120 |
| 5 | 5.00 | 18.00 | 2700 | 13.30 | 13.00 | 11.40 | 22.00 | 8.50 | 32.00 | 70.00 | 25 |
| 6 | 10.00 | 38.00 | 5500 | 30.00 | 30.00 | 24.00 | 50.00 | 19.00 | 74.00 | 168.00 | 30 |
| 7 | .25 | .75 | 180 | .57 | .38 | .48 | .53 | .32 | .78 | 2.35 | 100 |
| 8 | .42 | .92 | 350 | .73 | .50 | .64 | .80 | .44 | 1.30 | 3.33 | 150 |
| 9 | 6.00 | 28.00 | 2000 | 18.00 | 25.00 | 13.00 | 42.00 | 9.00 | 62.00 | 130.00 | 30 |
| 10 | 3.00 | 6.00 | 1500 | 4.70 | 3.60 | 4.00 | 6.50 | 2.90 | 11.00 | 31.00 | 100 |

B. Derived Unit-Hydrograph Parameters (continued)

| No. | $t_r$ | $t_p$ | $U_p$ | $t_{.75}$ | $d_{.75}$ | $t_{.50}$ | $d_{.50}$ | $t_{.25}$ | $d_{.25}$ | $t_b$ | a |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 11 | .50 | 1.00 | 560 | .83 | .57 | .70 | 1.00 | .50 | 1.50 | 6.00 | 140 |
| 12 | 1.50 | 4.25 | 1400 | 3.15 | 2.55 | 2.55 | 4.08 | 2.05 | 6.20 | 17.00 | 100 |
| 13 | 7.00 | 35.00 | 2400 | 24.70 | 34.00 | 19.20 | 58.00 | 13.00 | 92.00 | 181.00 | 20 |
| 14 | 2.00 | 8.00 | 1400 | 5.10 | 5.00 | 3.80 | 8.00 | 2.40 | 13.30 | 38.00 | 70 |
| 15 | 3.00 | 11.00 | 1200 | 8.40 | 7.30 | 6.90 | 12.20 | 3.80 | 24.20 | 58.00 | 40 |
| 16 | 9.00 | 36.00 | 3800 | 26.00 | 28.00 | 21.60 | 46.00 | 13.60 | 70.00 | 136.00 | 30 |
| 17 | 3.00 | 11.00 | 1600 | 6.70 | 7.60 | 5.70 | 12.00 | 4.00 | 17.60 | 41.00 | 50 |

C. Modified Unit-Hydrograph Parameters Using Fitted $t_r$ and a

| No. | $t_r'$ | $t_p$ | $U_p$ | $t_{.75}$ | $d_{.75}$ | $t_{.50}$ | $d_{.50}$ | $t_{.25}$ | $d_{.25}$ | $t_b$ | a' |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 7.15 | 39.57 | 2023 | 25.57 | 39.57 | 19.57 | 67.36 | 12.37 | 103.15 | 179.15 | 28 |
| 2 | .17 | .54 | 119 | .42 | .23 | .34 | .37 | .22 | .60 | 1.63 | 113 |
| 3 | 6.68 | 28.84 | 3008 | 19.84 | 23.84 | 14.84 | 39.76 | 8.84 | 60.68 | 124.68 | 27 |
| 4 | .39 | 1.06 | 304 | .81 | .48 | .58 | .79 | .31 | 1.27 | 2.72 | 126 |
| 5 | 5.05 | 18.03 | 2698 | 13.33 | 13.03 | 11.43 | 22.04 | 8.53 | 32.05 | 70.05 | 32 |
| 6 | 10.28 | 38.14 | 5493 | 30.14 | 30.14 | 24.14 | 50.21 | 19.14 | 74.28 | 168.28 | 23 |
| 7 | .24 | .75 | 181 | .57 | .38 | .48 | .52 | .32 | .77 | 2.34 | 114 |
| 8 | .41 | .91 | 351 | .72 | .49 | .63 | .79 | .43 | 1.29 | 3.32 | 117 |
| 9 | 6.07 | 28.03 | 1997 | 18.03 | 25.03 | 13.03 | 42.05 | 9.03 | 62.07 | 130.07 | 34 |
| 10 | 2.46 | 5.73 | 1541 | 4.43 | 3.33 | 3.73 | 6.10 | 2.63 | 10.46 | 30.46 | 77 |
| 11 | .59 | 1.04 | 543 | .87 | .61 | .74 | 1.07 | .54 | 1.59 | 6.09 | 192 |
| 12 | 1.65 | 4.33 | 1387 | 3.23 | 2.63 | 2.63 | 4.19 | 2.13 | 6.35 | 17.15 | 80 |
| 13 | 8.05 | 35.52 | 2371 | 25.22 | 34.52 | 19.72 | 58.79 | 13.52 | 93.05 | 182.05 | 27 |
| 14 | 2.17 | 8.08 | 1389 | 5.18 | 5.08 | 3.88 | 8.13 | 2.48 | 13.47 | 38.17 | 61 |
| 15 | 2.81 | 10.91 | 1208 | 8.31 | 7.21 | 6.81 | 12.06 | 3.71 | 24.01 | 57.81 | 44 |
| 16 | 8.59 | 35.79 | 3811 | 25.79 | 27.79 | 21.39 | 45.69 | 13.39 | 69.59 | 135.59 | 27 |
| 17 | 3.25 | 11.13 | 1586 | 6.83 | 7.73 | 5.83 | 12.19 | 4.13 | 17.85 | 41.25 | 54 |

D. Fitted Unit-Hydrograph Parameters

| No. | $t_r$ | $t_p$ | $U_p$ | $t_{.75}$ | $d_{.75}$ | $t_{.50}$ | $d_{.50}$ | $t_{.25}$ | $d_{.25}$ | $t_b$ | a |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 7.15 | 32.18 | 2944 | 22.35 | 26.68 | 17.64 | 44.54 | 11.24 | 69.20 | 141.65 | 28 |
| 2 | .17 | .54 | 126 | .41 | .24 | .34 | .36 | .21 | .57 | 1.46 | 113 |
| 3 | 6.68 | 31.54 | 2777 | 21.90 | 26.02 | 17.26 | 43.21 | 10.57 | 67.16 | 135.54 | 27 |
| 4 | .39 | .98 | 304 | .75 | .49 | .62 | .78 | .41 | 1.23 | 3.53 | 126 |
| 5 | 5.05 | 20.95 | 2084 | 14.71 | 16.26 | 11.64 | 26.80 | 7.96 | 41.76 | 87.00 | 32 |

D. Fitted Unit-Hydrograph Parameters (continued)

| No. | $t_r$ | $t_p$ | $U_p$ | $t_{.75}$ | $d_{.75}$ | $t_{.50}$ | $d_{.50}$ | $t_{.25}$ | $d_{.25}$ | $t_b$ | a |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 10.28 | 48.14 | 3785 | 33.04 | 42.32 | 25.95 | 70.92 | 17.22 | 109.93 | 215.72 | 23 |
| 7 | .24 | .70 | 178 | .54 | .33 | .44 | .50 | .28 | .80 | 2.11 | 114 |
| 8 | .41 | 1.11 | 321 | .85 | .56 | .69 | .89 | .44 | 1.42 | 3.97 | 117 |
| 9 | 6.07 | 23.56 | 2654 | 16.55 | 18.76 | 13.14 | 31.51 | 8.99 | 49.03 | 107.06 | 34 |
| 10 | 2.46 | 6.14 | 1503 | 4.52 | 4.08 | 3.67 | 6.96 | 2.81 | 10.89 | 30.12 | 77 |
| 11 | .59 | 1.06 | 588 | .83 | .55 | .69 | .94 | .49 | 1.49 | 5.23 | 192 |
| 12 | 1.65 | 4.62 | 1111 | 3.42 | 2.93 | 2.78 | 4.92 | 1.85 | 7.72 | 21.03 | 80 |
| 13 | 8.05 | 33.70 | 2996 | 23.37 | 28.12 | 18.43 | 46.91 | 13.27 | 72.86 | 147.82 | 27 |
| 14 | 2.17 | 7.46 | 1391 | 5.43 | 5.05 | 4.38 | 8.45 | 2.57 | 13.22 | 33.40 | 61 |
| 15 | 2.81 | 10.89 | 1425 | 7.80 | 7.70 | 6.22 | 12.64 | 3.93 | 19.77 | 44.54 | 44 |
| 16 | 8.59 | 36.04 | 3285 | 24.97 | 30.44 | 19.70 | 51.08 | 13.87 | 79.29 | 162.59 | 27 |
| 17 | 3.25 | 9.52 | 1610 | 6.88 | 6.67 | 5.53 | 11.18 | 4.34 | 17.48 | 42.95 | 54 |

# APPLICATION OF REGIONALIZED RELATIONS

The regional relations, expressing a unit hydrograph parameter as a function of one or more of the basin factors, can be stated in a general form:

$$\text{Unit hydrograph parameter} = c\, A^{\alpha}\, L^{\beta}\, S^{\gamma} \tag{1}$$

The applicable values of c, $\alpha$, $\beta$, and $\gamma$ for each of the 11 parameters and each of the 8 regions are given in Table 9. Where a basin factor does not enter the equation, the value of the exponent for that basin factor is zero and is shown by a dash. The information from this table can be used for developing a unit hydrograph for a drainage area (less than 400 square miles) after identifying the region in which this basin lies and developing the basin factors of A, L, and S.

<u>Example of Application</u>

A unit hydrograph, suitable for developing 100-year and PMF hydrographs, is needed for the Leaf River at Leaf River. The following information is available:

| | |
|---|---|
| USGS gaging station number | 05 441000 |
| Drainage area, A, square miles | 103 |
| Main-channel length, L, miles | 18.27 |
| Main-channel slope, S, ft/mi | 10.45 |
| Region number | 1 |

The unit-hydrograph parameters are calculated from equation 1 with values of c, $\alpha$, $\beta$, and $\gamma$ from Table 9:

$$t_r = 0.382\, A^{0.415}$$
$$= 2.61 \text{ hours}$$

TABLE 9. Coefficients and Exponents of Regional Equations

(Unit-Hydrograph Parameter = c A L S )

| * | $t_r$ | a | $U_p$ | $t_p$ | $t_{.75}$ | $t_{.50}$ | $t_{.25}$ | $d_{.75}$ | $d_{.50}$ | $d_{.25}$ | $t_b$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Region 1** | | | | | | | | | | | |
| c | 0.382 | 63.56 | 118.7 | 1.329 | 1.240 | 1.140 | 0.877 | 1.658 | 3.565 | 7.089 | 16.87 |
| α | 0.415 | - | 0.618 | 0.788 | 0.970 | 1.044 | 1.082 | 0.426 | 0.402 | 0.387 | 0.372 |
| β | - | - | - | -0.530 | -0.904 | -1.071 | -1.181 | - | - | - | - |
| γ | - | 0.246 | 0.393 | - | - | - | - | -0.266 | -0.336 | -0.383 | -0.326 |
| **Region 2** | | | | | | | | | | | |
| c | 0.628 | 184.0 | 360.0 | 3.000 | 1.605 | 1.333 | 0.900 | 1.066 | 1.558 | 2.143 | 6.211 |
| α | 0.435 | 0.670 | 0.867 | 0.421 | 0.456 | 0.444 | 0.442 | 0.295 | 0.187 | - | - |
| β | - | -1.360 | -0.708 | - | - | - | - | 0.416 | 0.617 | 0.943 | 0.855 |
| γ | - | 0.028 | - | -0.075 | - | - | - | - | - | - | - |
| **Region 3** | | | | | | | | | | | |
| c | 0.872 | 1.957 | 35.73 | 10.58 | 8.712 | 4.168 | 1.074 | 5.452 | 13.93 | 51.15 | 48.71 |
| α | 0.195 | 0.549 | 0.844 | 0.452 | 0.560 | 0.548 | 0.404 | 0.149 | 0.131 | 0.295 | 0.121 |
| β | 0.331 | 0.254 | - | -0.418 | -0.603 | -0.444 | - | - | - | -0.405 | 0.125 |
| γ | - | 0.214 | 0.273 | -0.186 | -0.210 | -0.138 | - | -0.078 | -0.232 | -0.351 | -0.211 |
| **Region 4** | | | | | | | | | | | |
| c | 0.150 | 13.76 | 73.91 | 5.275 | 3.787 | 2.751 | 1.852 | 3.342 | 5.765 | 11.23 | 19.68 |
| α | 0.151 | - | 0.692 | 0.336 | 0.333 | 0.343 | 0.356 | 0.347 | 0.331 | 0.313 | 0.358 |
| β | 0.695 | 0.257 | - | - | - | - | - | - | - | - | - |
| γ | - | 1.019 | 0.631 | -0.514 | -0.506 | -0.487 | -0.477 | -0.547 | -0.558 | -0.622 | -0.562 |

* denotes c, α, β, or γ

TABLE 9. Coefficients and Exponents of Regional Equations (continued)

**Region 5**

| * | $t_r$ | $a$ | $U_p$ | $t_p$ | $t_{.75}$ | $t_{.50}$ | $t_{.25}$ | $d_{.75}$ | $d_{.50}$ | $d_{.25}$ | $t_b$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| c | 0.474 | 3.777 | 43.76 | 4.539 | 3.600 | 3.005 | 2.223 | 4.561 | 9.184 | 23.40 | 55.73 |
| α | 0.482 | 0.256 | 0.701 | 0.388 | 0.374 | 0.374 | 0.369 | 0.360 | 0.334 | 0.289 | 0.281 |
| β | - | - | - | - | - | - | - | - | - | - | - |
| γ | -0.100 | 1.151 | 0.709 | -0.453 | -0.469 | -0.481 | -0.493 | -0.593 | -0.645 | -0.763 | -0.709 |

**Region 6**

| * | $t_r$ | $a$ | $U_p$ | $t_p$ | $t_{.75}$ | $t_{.50}$ | $t_{.25}$ | $d_{.75}$ | $d_{.50}$ | $d_{.25}$ | $t_b$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| c | 0.566 | 230.4 | 261.9 | 1.668 | 1.228 | 0.907 | 0.601 | 1.020 | 1.888 | 3.320 | 9.151 |
| α | 0.231 | -0.214 | 0.505 | 0.490 | 0.485 | 0.494 | 0.508 | 0.534 | 0.517 | 0.496 | 0.463 |
| β | 0.334 | - | - | - | - | - | - | - | - | - | - |
| γ | - | -0.679 | - | - | - | - | - | - | - | - | - |

**Region 7**

| * | $t_r$ | $a$ | $U_p$ | $t_p$ | $t_{.75}$ | $t_{.50}$ | $t_{.25}$ | $d_{.75}$ | $d_{.50}$ | $d_{.25}$ | $t_b$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| c | 1.215 | 1.965 | 55.22 | 3.950 | 2.849 | 2.137 | 1.323 | 3.365 | 7.326 | 15.53 | 31.92 |
| α | 0.345 | - | 0.473 | 0.403 | 0.406 | 0.416 | 0.428 | 0.409 | 0.378 | 0.351 | 0.364 |
| β | - | 0.689 | 0.279 | - | - | - | - | - | - | - | - |
| γ | -0.290 | 1.072 | 0.608 | -0.380 | -0.393 | -0.371 | -0.327 | -0.486 | -0.576 | -0.653 | -0.573 |

**Region 8**

| * | $t_r$ | $a$ | $U_p$ | $t_p$ | $t_{.75}$ | $t_{.50}$ | $t_{.25}$ | $d_{.75}$ | $d_{.50}$ | $d_{.25}$ | $t_b$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| c | 0.475 | 7.694 | 106.0 | 8.318 | 5.703 | 4.218 | 1.687 | 5.005 | 6.334 | 10.02 | 9.877 |
| α | 0.287 | 0.111 | 0.547 | 0.329 | 0.327 | 0.334 | 0.104 | 0.394 | 0.434 | 0.431 | 0.516 |
| β | 0.322 | - | - | - | - | - | 0.460 | - | - | - | - |
| γ | - | 0.645 | 0.339 | -0.416 | -0.391 | -0.367 | -0.307 | -0.446 | -0.387 | -0.387 | -0.133 |

* denotes c, α, β, or γ

$t_r = 0.382\ A^{0.415}$
$t_r = 2.61$ hours } Page 75

$$a = 63.56\ S^{0.246}$$
$$= 113 \text{ cfs/hour}$$
$$U_p = 118.7\ A^{0.618}\ S^{0.393}$$
$$= 5235 \text{ cfs}$$
$$t_p = 1.329\ A^{0.788}\ L^{-0.530}$$
$$= 10.99 \text{ hours}$$
$$t_{.75} = 1.240\ A^{0.970}\ L^{-0.904}$$
$$= 8.04 \text{ hours}$$
$$t_{.50} = 1.140\ A^{1.044}\ L^{-1.071}$$
$$= 6.41 \text{ hours}$$
$$t_{.25} = 0.877\ A^{1.082}\ L^{-1.181}$$
$$= 4.27 \text{ hours}$$
$$d_{.75} = 1.658\ A^{0.426}\ S^{-0.266}$$
$$= 6.40 \text{ hours}$$
$$d_{.50} = 3.565\ A^{0.402}\ S^{-0.336}$$
$$= 10.44 \text{ hours}$$
$$d_{.25} = 7.089\ A^{0.387}\ S^{-0.383}$$
$$= 17.35 \text{ hours}$$
$$t_b = 16.87\ A^{0.372}\ S^{-0.326}$$
$$= 44.02 \text{ hours}$$

$t_r = 2.61$ hrs

A unit hydrograph duration of 2.5 or 3.0 hours will be suitable not only for defining unit hydrograph ordinates on the graph but also for deriving the surface runoff hydrograph with effective rainfall values specified at half-hourly or hourly intervals. A duration of 3.0 hours is selected, and 45 unit hydrograph ordinates at 1-hour intervals are sufficient for synthesizing flood hydrographs satisfactorily. The values of unit hydrograph parameters (with the exception of a) are modified accordingly:

$$t_R = 3 \text{ hours}$$

$$U_p = 5235 - \overset{a}{113}(3.0 - 2.61)$$

$$= 5191 \text{ cfs}$$

$$t_p = 10.99 + 0.5(3.0 - 2.61)$$

$$= 11.19 \text{ hours}$$

$$t_{.75} = 8.04 + 0.5(3.0 - 2.61)$$

$$= 8.24 \text{ hours}$$

$$t_{.50} = 6.41 + 0.5(3.0 - 2.61)$$

$$= 6.61 \text{ hours}$$

$$t_{.25} = 4.27 + 0.5(3.0 - 2.61)$$

$$= 4.47 \text{ hours}$$

$$d_{.75} = 6.40 + 0.5(3.0 - 2.61)$$

$$= 6.60 \text{ hours}$$

$$d_{.50} = 10.44 + 0.75(3.0 - 2.61)$$

$$= 10.73 \text{ hours}$$

$$d_{.25} = 17.35 + (3.0 - 2.61)$$

$$= 17.74 \text{ hours}$$

$$t_b = 44.02 + (3.0 - 2.61)$$

$$= 44.41 \text{ hours}$$

The unit hydrograph is drawn in figure 12 with the above parameters. The measured surface runoff represented by this unit hydrograph is 1.00 inch.

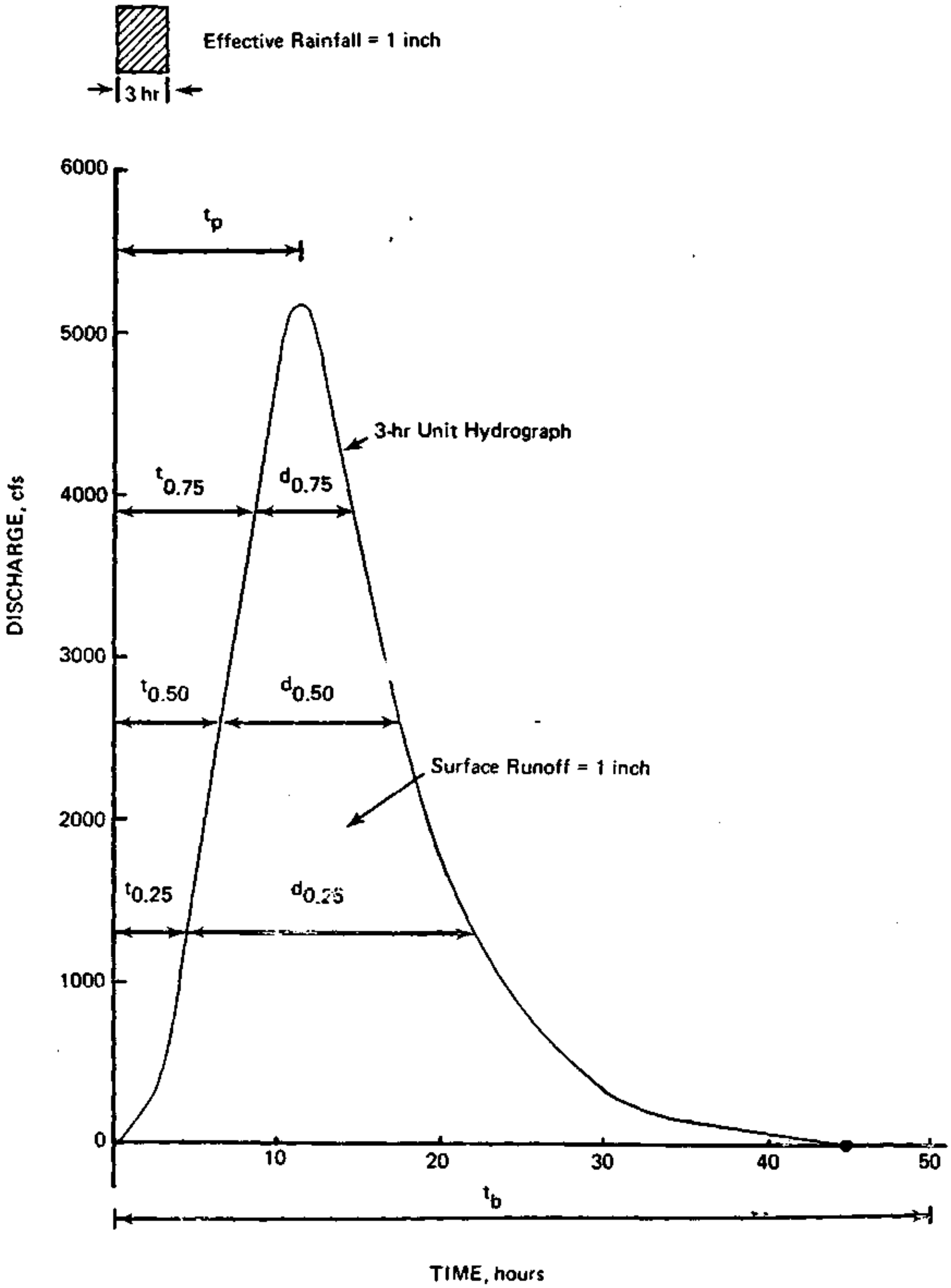



Figure 12. Unit hydrograph for Leaf River at Leaf River

of time parameters and reduces the peak, whereas a shorter length and/or steeper slope decreases the magnitude of time parameters and increases the peak. Any effect on the unit hydrograph parameters of considerable variations in L and S from those used for the regional regressions can be evaluated to some extent from the information given for basins studied for each of the 8 regions.

4) The study basins in the 7 regions other than region 3 contain insignificant to small percentages of urbanized areas. The basin of Boneyard Creek near Urbana, a highly urbanized basin, was not considered in developing relations for region 6 because its response was greatly different from the other 10 basins that are non-urbanized or contain small amounts of urbanization. Thus, the regional relations or equations for determining unit hydrograph parameters (for all regions except region 3) do not apply to small but considerably urbanized basins.

5) Small basins, covered mostly by forests or having significant extra storage in the form of quarries and cut-impoundments, behave differently than the basins without these extra storage factors. Unit hydrographs developed for such basins from the regional equations in this report will have to be modified to account for such local effects.

6) Parameter a, one of the 11 unit hydrograph parameters, serves the purpose of modifying the unit hydrograph peak for a small change in value of $t_r$. If the $t_r$ is to be changed significantly, a minor change may be affected with a and then the S-curve method may be used to determine the unit hydrograph of the desired duration.

7) If the basin for which a unit hydrograph is needed has two major and distinct streams joining a relatively small distance upstream of the

point under consideration, the unit hydrograph may be determined for each branch separately and then routed through the main stem downstream of the junction to obtain the desired unit hydrograph. The peak of the unit hydrograph will be higher than otherwise if the peaks from the two branches occur at about the same time.

8) If the basin for which the unit hydrograph is to be determined is near the boundary of a region, the unit hydrographs may be determined from the equations for that basin and also from those for the adjacent basin. The supplementary information, together with any physical or other data, may be considered in modification of the unit hydrograph, if deemed necessary.

9) The synthetic unit hydrograph equations developed for the 8 regions cannot be used directly for basins largely affected by man-made structures or flow regulation. The unit hydrograph and the hydrographs can be developed for the unregulated condition. The hydrographs will then have to be modified based on the flow regulation **procedures** together with the expected conditions at the beginning of the flood hydrograph.

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